FOOD TECHNOLOGY

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VOLUME II

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INDEX—VOLUME II

A marvelous product—but not patentable, 278
Aged, food for, 256
Air flow through beds of dehydrated vegetables, 33
Analyses, need for interpretation of, 3
ANDERSEN, A. A., 180
An opportunity and an obligation, 177
Award, Stephen M. Babcock, 348

Bacterial spores, technique for studying resistance of, to temperatures in the higher range, 228
Bacteriological considerations relating to process evaluation, 115
BALL, CHARLES OLIN, 54, 55, 88, 290
BARTHOLOMEW, JAMES W., 91
Benzene hexachloride in canned peaches, 303
Benzoic acid (s),
  effect of, on spoilage organisms, 112
  germicidal value of esters of, 23
BERRY, J. A., 180
Blanching, radar energy for, 95
BLANCK, FRED C., 349
BOHN, RALPH M., 263
Boston Brown bread, electronic preservation of, 91
BRENNER, SADIE, 207

C. F., 4
CALESNICK, ELEANOR J., 9
Canadian food technologists, salute to, 290
Canned foods
  effect of high temperature storage on retention of nutrients in, 207
  nutritive value of, 133
CARTWRIGHT, L. C., 330
CATHCART, W. H., 3
Cationic surface active agents, comments on standardization of test methods for, 163
Chloramine T, sanitizing hands using a germicide containing, 105
Clostridium botulinum, studies of, in frozen pack vegetables, 180
Colloid chemistry, importance of in food technology, 144
Company financing, relation of technology to sound, 167
Congratulations, Doctor Woolley, 179
CONKLIN, DWIGHT B., 105
Consumer acceptance survey, 322
Costs, methods of obtaining, of research projects, 170
Creative thinking—a priceless ingredient, 4
CROCKER, E. C., 317
Crystallographic method, new, for the study of changes in processed foods, 191

Dairy industry, methods used by, to improve sanitary control, 39
DAVIS, LYLE L., 303
Dehydrated vegetables, air flow through beds of, 33
Development, organization and management of research and, 69
DORN, HERMAN W., 7
Dried fruit industry, continuous sanitizing of equipment in, 292
DUNLOP, STUART G., 207

Effect of different processing procedures on venting and loss of liquid from home canning jars, 222
Efficiency in changing the Institute Administration, 88
Egg(s)
  molds in spray-dried whole, 15
  powder, isolation of Salmonella from, and their heat resistance, 9
  spray-dried whole, microbiology of, 15
Electronic preservation of Boston Brown bread, 91
ELVEHJEM, C. A., 340
Error in considering research overhead, 7
ESSELEN, W. B., JR., 222
Evaluation of foam-producing agents, 263
Experiment, mathematics and, in food technology, 55

FELLERS, C. R., 222
FEVOLD, H. L., 201
Financing, company, relation of technology to, 167
Fisheries
  possibilities in developing by-products, 268
  technical seminar, 352
Foam-producing agents, evaluation of, 263
Food
  for infants, invalids and the aged, 256
  processing, possible practical application of histological research to, 158
    role of control instruments in continuous, 359
  quality, a rational method for grading, 241
  value of soybean protein as related to processing, 201
Food technology
  importance of colloid chemistry in, 144
  mathematics and experiment in, 55
  role of, in modern nutrition, 340
  what it has done for our business, 340
FRIESS, HANS, 191
Frozen pack vegetables, studies of *Clostridium botulinum* in, 180
Fundamental training is important, 290

Glycols, study of the germicidal value of, 23
GOLDBLITH, SAMUEL A., 95
Good human relations pay dividends, 81

Hands, sanitizing, using a germicide containing Chloramine T, 105
HARRIS, R. G., 91
HARRISON, GEORGE RUSSELL, 45
HAUSER, E. A., 144
HEID, J. L., 289
HEIM, HAROLD C., 23
HESTER, JACKSON B., 297
HILL, BARBARA, 201
Histological research, possible practical application of, to food processing, 158
HOHL, LEONORA A., 158
HOLMES, ARTHUR D., 252
Hormone treatment of field grown tomatoes, some results of, 252
Human relations, good, pay dividends, 81

Industrial and legal viewpoints, 289
Infants, food for, 256
Institute administration, efficiency in changing the, 88
Instruments, control, role of in continuous foor processing, 359
Invalids, food for, 256
Inventions, simple, pay dividends, 64

KOHMAN, EDWARD F., 256
KLOSE, A. A., 201
KNOWLES, JOHN T., 51
KUYPER, ADRIAN C., 308
KUZMESKI, JOHN W., 252

LACHMAN, WILLIAM H., 252
LAING, M. L., 177
LIND, H. E., 163

Management, relation of technology to company, 75
MARSHALL, ROYE, 133
Mathematics and experiment in food technology, 55
McCAULEY, L. E., 69
McCLUNG, L. S., 179
McCORMICK, CHARLES P., 81
McFARLANE, VERNON, 15
Methods of obtaining costs of research projects, 170
Molds, in spray-dried whole egg, 15
Monosodium glutamate, role of, in seasoning certain vegetables, 317
MORSE, RICHARD L. D., 322

NANZ, ROBERT A., 330
Nicholas Appert Medal
  presentation to Charles Olin Ball, 51
  to C. A. Elvehjem, 340
Nutrition, modern, role of food technology in, 340
Nutritive value of canned foods, 133, 228
NYDICK, A. J., 64, 278

ORTEN, JAMES M., 308
Overhead, error in considering research, 7

PARFITT, E. M., 39
Peaches, canned, benzene hexachloride in, 303
PERRY, HELEN, 180
PILLSBURY, PHILIP W., 75
PLANCK, R. P., 241
POE, CHARLES F., 23, 112
Preservation, electronic, of Boston Brown bread, 91
Process evaluation, bacteriological considerations relating to, 115
PROCTOR, B. E., 3, 95
Processed foods, a new crystallographic method for the study of changes in, 191
Processing procedures, effect of different, on venting and loss of liquid from home canning jars, 222
Professional organization, importance of service in, 3
Propyl gallate, studies on the toxicity of, and of antioxidant mixtures containing propyl gallate, 308

Radar energy for rapid food cooking and blanching and its effect on vitamin content, 95
RECTOR, THOMAS M., 170
Research
  organization and management of, 69
  overhead, error in considering, 7
  projects, methods of obtaining costs of, 170
RILEY, HERBERT N., 283
ROBERTSON, WM. F., 133

Salmonella organisms, heat resistance of, and isolation from spray-dried whole-egg powder, 9
SALOWEY, MATHILDE, 9
Sanitary control, methods used by the dairy industry for the purpose of, 39
Sanitizing
  continuous, of equipment in the dried fruit industry, 292
  hands using a germicide containing Chloramine T, 105
Science, new advances in, 45
Service, importance of, in a professional organization, 3
SJOSTROM, L. B., 317
SLATER, L. E., 359
Soil treatment for better foods, 297
SMITH, ARTHUR H., 308
SMITH, C. TYSON, 252
SMITH, EDWARD E., 292
SOTIER, ALFRED L., 105
Soybean protein, food value of, as related to processing, 201
SPAUGH, O. H., 33
Spices, comparative evaluation of, 330
Standardization of test methods for cationic surface active agents, comments on, 163
STATELER, E. S., 337

Storage, high temperature, effect of, on retention of nutrients in canned foods, 207
STUMBO, C. R., 112, 228
SUSSEX, FRANK, 91
SUTTON, RUTH R., 9
Survey, consumer acceptance, 322

TARR, H. L. A., 268
Technology
relation of, to company management, 75
to sound company financing, 167
Tomatoes, some results of hormone treatment of field-grown, 252
TOWNSEND, C. T., 180

VAUGHN, REESE H., 292
Vegetables,
dehydrated, air flow through beds of, 33
frozen pack, studies on *Clostridium botulinum* in, 180
handling and storage procedures for, prior to canning, 133
monosodium glutamate in the seasoning of certain, 317
Venting and loss of liquid from home canning jars, effect of different processing procedures on, 222
Vitamin content, effect of radar energy on, in food, 95

WATSON, ALICE J., 15
What food technology has done for our business, 283
WHITTEMORE, L. F., 167
WINTER, FRANK H., 292
WODICKA, VIRGIL O., 207
Woolley, Doctor, congratulations, 179
WYSS, ARTHUR P., 112

TP
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1948

FOOD TECHNOLOGY

CONTENTS

Editorials
Importance of Service in a Professional Organization
Need for Interpretation of Analyses
Creative Thinking—A Primary Ingredient
The Error in Considering Research Overhead

Heat Resistance of Salmonella Organisms Isolated from Spray-Dried Whole Egg Powder. Mathilde Salzwedel, Ruth E. Stadler, and Eleanor J. Schwalm

Microbiology of Spray-Dried Whole Egg. IV. Models. Allen J. Wesson and Ruppel H. McFarlane

A Study of the Germicidal Value of Glycols, Glycol Dusting, and Related Compounds. H. C. Haas and C. F. Poe

Air Flow Through Beds of Polydisperse Vegetables. G. E. Spaugh

Methods Used by the Dairy Industry to Improve Sanitary Control Through Equipment Design. Dairy Products and Liquid Foods. R. E. Parks

New Advances in Solubles. G. E. Harrison

Nicholas Appert Medal Presentation. John T. Knowles

Response, Upon Receiving the Nicholas Appert Medal. C. Olin Ball

Mathematics and Experience in Food Technology. C. Olin Ball

Current Patents and Patent Litigation
Simple Inventions Pay Dividends. A. J. Hyslop

Industrial and Legal Viewpoints
Organization and Management of Research and Development. L. E. Hackedorn
Relation of Technology to Company Management. Philip W. Pillsbury

News of the Institute

Regional Section News

Selected Abstracts

Index

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FOOD TECHNOLOGY

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Editorial

Importance of Service in a Professional Organization

Many factors contribute to the continued prosperity and success of a professional organization, but perhaps no single factor is more important than that of service rendered either to fellow members or others. A signal example of such a high type of service is the recently inaugurated Speaker's Bureau of the Chicago Section (cited on pp. 2-3), an example that might well be emulated by all the local sections of I. F. T. Not only will this type of community service make the general public better acquainted with food technology and its progress, but it is bound to benefit the I. F. T. organization by widening the scope of our own interests and by more rapidly bringing the realization of our profession to responsible lay people in public places and in industry. We suspect that it may also result in some of our members becoming more accomplished public speakers, which in itself is a worthy objective.

In recent years it has frequently been maintained that one of the crying needs in many communities has been for active participation in local and public affairs by professional men who know what they are talking about and who have facts to offer instead of theories. Perhaps this example mentioned above, for which we commend the Chicago Section, may stimulate some of our readers to wonder whether an effort in this direction might not be worthwhile for their sections and perhaps even for themselves.

Why not get out one of your favorite food technology subjects, perhaps the story of your industry, or process, or product, polish up the dusty (or unwritten) outline for a few evenings and tell your local section secretary you are a volunteer for his speaker's bureau? Sometimes editors wonder if any one ever reads editorials. Could we find out by running a Gallup poll on how many speaker candidates the local secretaries report in the next four weeks?

B. E. Proctor.

Need for Interpretation of Analyses

Processed foods, with few exceptions, have been developed without benefit of scientific research. Art, rather than science was, and in many instances still is, the basis of operation. In general, the production man has turned to the scientist only when an emergency arose. Nevertheless, there is a significant trend in the processed foods industry toward a greater use of scientific knowledge. This is evident when one considers investigations that have been carried out at universities, state and federal laboratories and at the laboratories of many of our large food processing companies. This interest is growing due to the realization by some persons concerned with foods, that research, on the fundamental problems of food processing, pays dividends. However, greater interest is needed in research on the basic problems of food processing. It is believed that greater interest can be obtained by explaining

*Refers to Chicago Section News under "News of Regional Sections."

Editorial

to the production man the meaning of scientific investigation and research that may concern him.

We have many methods which may be used for determining the various constituents of food products, but not sufficient information as to the interpretation of results. The agricultural scientist has amassed a great number of official methods so that we have a means for determining basic constituents and can be sure that the results obtained by different workers using the same official method are comparable. Through the use of such procedures as those developed and published by the A.O.A.C., the A.A.C.C., and other similar groups, workers should be able to obtain results that are accurate and comparable as long as the procedures are followed properly. But even when we have these results, their interpretation is another problem. A student who has been properly trained in college should be able to carry out analyses satisfactorily, but may well be at a loss to know what the results mean when he has them. Much has been written over the years as to the significance of various analytical results under particular circumstances; but, in general, this material has not been assembled so that it is as readily available as are the analytical methods. More publications similar to Woodman's "Food Analysis" that contains information on the interpretation of results as well as procedures would be desirable. Possibly, there are other publications which in one manner or another do an equally satisfactory job. A good example, not dealing with foods, however, are the procedures and publications of the American Society of Testing Materials. This society has compiled publications on the significance of their standard procedures which are very helpful.

It must be admitted that particular branches of the food industry may place different values on the same test, but for the industry in general, there should be a common basis for the evaluation of the greater part of them. The problem of the interpretation of results is particularly acute in the case of the small processor who may be employing a technologist of limited experience, or a consulting laboratory with limited experience on the point in question. It is believed that more readily available interpretations of standard tests will allow the small processor to receive more meaningful results, and in turn make the whole industry more desirous of obtaining and using scientific information. Perhaps the incorporation of interpretations of standard tests in the same volume with the tests themselves would be the most expedient way to handle this problem.

W. H. CATHCART.

Creative Thinking—A Priceless Ingredient

Theodore Weicker, one of the creators of E. R. Squibb and Sons, stated his fundamental philosophy in business as follows:

> "The priceless ingredient in any product is the honor and integrity of its maker."

This statement will go ringing down the years, a challenge to succeeding generations.

Only by research, by the application of creative ideas can the honor and integrity of the maker be maintained. In developing new products and in perfecting present products creative activity is a priceless factor. Without this activity progress is impossible.

Let us analyze some of the important factors involved in our complicated industry of today, where many hands and many ideas are integrated to

produce the finished product. What are some of the important factors involved in the development of a productive scientific personnel?

In 1920, 29 million dollars were spent on research by industrial concerns. Nine thousand three hundred persons were engaged in research.

In 1930, industry in the U. S. spent 160 million dollars on industrial research, and in 1940, 240 million dollars. Seventy thousand workers were engaged in research activities in 1940.

In 1947, the U. S. was expending, according to the Steelman report, 1,160,000,000 dollars for all research combined. Industry was investing 450 million dollars. The Federal Government was expending 625 million dollars, 500 million of which was spent in research for the war and navy. The universities were expending 45 million dollars, and institutions other than government and universities were expending about 40 million dollars. Approximately 130,000 workers are engaged in research activity today.

It is estimated that someone must save about $24,000 to put a research man to work. How does management justify placing so large an investment in research activities? We are told that research is insurance against competition and displacement by new inventions. It is assumed that research today will guarantee the prosperity of tomorrow. Based on this philosophy, business and government are expanding laboratories and are building new ones in an effort to broaden and intensify the research effort.

Where are the men to be obtained to operate these laboratories, and are the outstanding men with creative ability available to supply the leadership?

The Vannevar Bush report indicates a shortage of 150,000 B.S. men and 16,800 Ph.D. graduates between the years 1941 and 1955. Are we proceeding intelligently to select research men and are the most intelligent men being selected for training? Human engineering studies show that we are wasting the lives of many talented people who have not had an opportunity to enter college. During the war, AGCT, according to the *Industrial Bulletin* of A. D. Little, selected two grades of men, and from these two grades most of the officers were selected. Most college men fell into Grade I or II. However, two million non-college men also qualified for the grade. Their training was far below the level of college training.

Five thousand men above the average college grade in intelligence had not finished grammar school. Seventy-eight thousand men above the average college grade had not finished high school, and 490,000 men, also rating above the average college grade, had finished high school but had not completed college work. It is interesting to point out that 9 per cent of boiler makers did as well in the Army tests as the average lawyer. While there was some relation between native ability, previous training and the occupation the men were following, generally there was a vast gap between talent and its utilization, indicating a terrific waste of human resources.

The need for better classification of human potentialities in high schools, junior colleges, and in universities seems evident. More training in the arts may be desirable in the high schools and junior colleges for people with less gifted potentialities. It is also possible that industry and the professions have not offered the proper incentive to stimulate the young men, but a reservoir of talent remains undeveloped. It is desirable to hold the universities open to men who have the highest abilities, but if the above infor-

mation is reliable further selection and sifting may be necessary.

It is questionable whether or not a four-year course in college is sufficient for the chemist and engineer. He does not have time to become fully acquainted with the basic sciences underlying his field of activity or with the knowledge of economic problems, patents and patent law, and to develop good use of the English language, during this short period. Among the college men we shall seek to find most of the leadership and creative ability to carry on the future activities of our scientific professional and industrial life. Perhaps our industrial and research demands would be met more effectively if further training could be given to the more promising men, many of whom do not have means, or encouragement, to continue their work by entering the graduate school. Industry, and possibly government, may find it desirable to support increasingly, and in larger measure, fellowships and grants for graduate school study. This does not mean that we should pamper graduate students, but it is to the interest of the nation to see that creative ability is given every opportunity. Grants-in-aid to assist the science departments in the development of equipment and in the maintenance of adequate graduate facilities may be matters that will receive more attention in the future.

Industrial laboratories are not free from criticism in respect to the utilization of well trained scientific men. Management has not always learned how to integrate the fundamental work of the scientists into its economy. Competent scientific men are often assigned to routine tasks, and their creative activity is stifled by subjecting them to the direction of men who have no professional background or any interest in creative science. Such action is indicative of untrained and ignorant management.

The recent action of certain large industrial concerns in establishing higher salary classifications, comparable with those received by management, for research men who show exceptional creative ability is to be commended and, if properly carried out, this type of recognition should serve to stimulate the interest of men possessed of high creative ability in following research as a career.

A new set of factors in evaluating personnel is involved. Administrative effectiveness and the ability to handle large aggregations of men have always been highly paid by industry. However, factors such as unique creative ability may be equally important in determining the effectiveness of management and the success of business enterprises based essentially on science.

Some way of avoiding this waste of human material should be found. The most important factor in advancing knowledge is the well-trained individual with creative ability and the proper environment. Scientific men must be supported by capital and labor. Merely to fill laboratories with men will not produce new scientific discoveries and advancement of knowledge. Our wealth in materials, our good laboratories, and our large business organizations will not be efficiently utilized unless we have in the laboratories and in production a sufficient number of men with creative intelligence, who can utilize these facilities to the best advantage.

As E. C. Williams so well states, "It is in the intellectual calibre and vision of the research man that the potential of modern industry lies;—the potential can never be reached without equal vision and courage in the executive department."

C. F.

Editorial

The Error in Considering Research Overhead

There is little so pathetic as the processor or manufacturer who is brought to the unhappy realization that his product is no longer the preferred one on the open market. This is a situation which even sales can not overcome. Such a circumstance usually is the primary incentive for the manufacturer to compare his product with that of his successful competitor. When and if this preliminary investigation suggests the possible reasons for the failure of his product, he has already entered a stage of research which should lead not only to the improvement of his wares, but to the full anticipation of future requirements and advancements beyond the ken of current competition.

Management is therefore immediately faced with a dual course for survival: (1) to run the organization for maintenance of the status quo as a minimum requirement and, (2) to *act* upon the facts established as a result of critical, exhaustive inquiry and experimentation on old and new products alike. The latter course must be delegated to those specifically trained and experienced in the endeavor. Particularly, the guidance of the program should be entrusted to a scientifically developed, practical leadership functioning as a part of top management. In this way, the research activities will have the proper integrative interpretation to fit them into functional policy.

In many large concerns, the research laboratories are developed as a tax-dodge. This is comparable to the showplace laboratories where walls have been set up as easily removable partitions to permit ready conversion to a gymnasium, auditorium, display room, club rooms, sales convention rooms—for anything but the original purpose. This type of structure is not to be so heartily condemned as a fraud and hypocrisy upon the Bureau of Internal Revenue as for the mirage it creates for management. Here, it permits organizational diagrams to be drawn figuratively and literally using the word "research." This is supposed automatically to confer "know-how" and scientific ability upon those concerned, as well as give the stockholders and the annual report a respectable outlook.

Research as applied to the food industry represents a principle possessing the same significance that it does for any other industry whether it be foods for the better maintenance of life, or ammunition for its destruction. Admiral H. G. Bowen recently stated, "A first-rate power must be in science up to the hilt if it expects to survive."

Invariably, especially within management of large corporations, there exists a sterile nucleus capable of acknowledging the need to accomplish a profit, but does not appreciate the planned means to that vital goal. These personalities are usually classified as being too busy earning a living to think. For them, research offers the results of efforts of the abstract—and applied—investigators. In this manner, the channelized mind can be rescued from preconceived, prejudiced and outmoded ideas.

Research may be a system of trials and errors which ultimately produces a group of worthwhile facts that can be converted into statements describing accurately what *has* happened, e.g., process failures, and what *will* happen, e.g., assurance of process success, under given sets of conditions. Such information should be applied to company products as well as those of competition to reveal both the advantages and disadvantages. How these data are exploited will be dictated by the position research holds in the governing

body. If management disregards its research facilities in order to favor unevaluated pet projects, and this always occurs when management feels research is taking too long to prove something is right or wrong (both may consume the same period of time), disaster is inevitable. Then, indeed, does research become overhead; but so does the rest of management, if the stockholders are big and intelligent enough.

Many of the successful industries now spend over 4% of their gross annual income for research. This is very low when it is realized that research is the key to new products, new processes, new customers, confidence in the face of recession and assurance against competition. Even so-called "negative" research is contributory for it reveals, with a small investment loss, that a certain path can lead only to failure.

Research is the *vision* of management, and is today's investment for tomorrow's success.

HERMAN W. DORN.

HEAT RESISTANCE OF *SALMONELLA* ORGANISMS ISOLATED FROM SPRAY-DRIED WHOLE-EGG POWDER

MATHILDE SOLOWEY, RUTH R. SUTTON AND ELEANOR J. CALESNICK
Microbiology Research Division, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture

On the basis of Decimal Reduction Times of Salmonella and other Gram-negative bacteria, the data presented in this paper suggest that flash pasteurization at 60°C. of liquid egg would reduce the number of these organisms to a marked degree, should they be present.

Quartermaster Corps Tentative Specification *(6)* for the production of low-moisture (not more than 2 percent), spray-dried whole-egg powder provides that "The liquid egg just prior to drying shall be preheated by the flash method to not more than 140° F." (60° C.). Although effective in reducing the incidence of *Salmonella*-positive samples of powder, these conditions have not resulted in the complete elimination of *Salmonella* organisms from the final product. Schneider *(8, 9)* reported an incidence of 1.4 to 1.63 percent *Salmonella*-positive samples of low-moisture powder; McFarlane and Calesnick *(5)* reported an incidence of 5 percent. Winter et al. *(11, 12)*, reporting on the destruction of *Salmonella* in liquid egg, stated that, although there was some indication of type variation with respect to heat resistance, on the whole, *Salmonella* organisms were not difficult to destroy in the laboratory pasteurization unit employed.

This investigation was undertaken to evaluate the lethal effects of heat on *Salmonella* in liquid whole egg under laboratory conditions at temperatures approximating commercial pasteurization. The Decimal Reduction Time (DRT) of Katzin, Sandholzer, and Strong *(4)* was used as the criterion because it offers a simple, relatively accurate measure for obtaining comparative data. As stated by the authors, the DRT is "based on the application of the monomolecular reaction rate constant to bacterial death under uniform test conditions." Rahn *(7)* defines it as "the time required to reduce the bacterial population to 10 percent of the original number."

PROCEDURE

Organisms studied: Ninety-five cultures, representing 24 *Salmonella* types, and 21 other Gram-negative cultures were used; i. e., 7 paracolon, 6 *Aerobacter*, 4 *Pseudomonas*, and 4 *Escherichia coli*. All were originally isolated from samples of high-moisture (4 to 6 percent), spray-dried whole-egg powder, with the exception of 2 old laboratory strains of *E. coli* whose original source is not known.

Culture and test media: Two media were used, liquid whole egg (prepared from freshly broken out grade A shell eggs as needed), pH 7.4 to 7.6, and tryptose (Difco) broth, pH 7.6.

Methods: Tubes of sterile liquid egg were inoculated with 18-hour cultures of the test organisms grown in liquid egg at 37° C. Similarly, tubes of tryptose broth were inoculated in the same manner with the test organisms grown in tryptose broth. In each case, the aliquot of culture added was sufficient to give a known concentration of 1 to 3 million cells per milliliter, as determined by plating on tryptose agar. The inoculated test liquid was then pipetted in 3.5 ml. amounts into sterile, cotton-stoppered, thin-walled 75- by 12-mm. test tubes. Just prior to introducing the pipette into the test tube, excess liquid on the outside of the pipette was carefully wiped off with sterile filter paper. In withdrawing the pipette, special

care was taken to avoid touching the tip to any part of the tube above the level of the liquid.

The tubed suspensions were heated in a thermostatically controlled water bath fitted with a continuously operating electric stirrer. The fluid within the tubes reached test temperatures within 1½ to 2 minutes. Levels of the suspensions were kept well below that of the water in the bath.

The majority of the tubed suspensions were heated for 3 minutes at 58° C. DRT determinations were run in duplicate and later checked again in duplicate. The DRT's of 40 *Salmonella* cultures were further checked by determining the number of survivors at each of two time intervals at a specified temperature. For these tests, quadruplicate tubes were filled with the appropriate amounts of inoculated liquid, two tubes being removed at the end of the first heating period and two at the end of the second. In another phase of the investigation, the effect of heating for 1, 2 and 3 minutes at different temperatures was determined for 11 cultures representing 7 *Salmonella* types. Ten of the cultures were studied over the range 54° to 58° C. The range was extended to 62° for the eleventh culture which was known to be more heat resistant. As previously, determinations were made in duplicate for each experimental condition, that is, two tubes, each containing 3.5-ml. aliquots of the same suspension, were removed from the bath for examination at the end of each 1-, 2- and 3-minute exposure interval at a given temperature. The determinations were repeated 3 to 5 times for each culture both in liquid egg and in tryptose broth.

Immediately at the end of the heating periods, and preparatory to sampling, the tubes were quickly cooled to 15° to 20° C. in ice water. Counts of the surviving organisms were determined (a) by plating and (b) by a modification of the Hoskins' *(3)* Most Probable Numbers (MPN) technic. By the first technic, serial dilutions were plated in duplicate or triplicate on tryptose (Difco) agar, and the plates were incubated for 48 hours at 37° C. By the MPN technic, a 1:33 dilution of the heated liquid in 0.85 percent physiological saline was made (3 ml. of the test liquid plus 96 ml. of saline). Fifteen tubes of tryptose broth were inoculated—five with 10 ml., five with 1 ml., and five with 0.1 ml. of the 1:33 dilution of culture. The tubes were incubated for 48 hours at 37° and then streaked out on *Shigella-Salmonella* (Difco) agar plates. Growth appearing on the plates after incubation for 18 hours at 37° was tentatively confirmed as *Salmonella* by slide agglutination of picked colonies with appropriate antisera. The number of *Salmonella* surviving the heating was determined by reference to the appropriate table. For the identification of recovered organisms other than *Salmonella* the requisite confirmatory tests were made.

The Decimal Reduction Times of the cultures were calculated as described by Katzin, Sandholzer, and Strong *(4)*, according to the formula: "$DRT = 2.3/K = (t_2 - t_1)/\log_{10}(C_1/C_2)$, where K is the monomolecular reaction rate constant, and C_1 and C_2 are the initial and final concentrations of bacteria, respectively, subjected to a constant lethal temperature for $(t_2 - t_1)$ minutes."

RESULTS

Table 1 summarizes the DRT's at 58° C. of 91 *Salmonella* strains and 21 miscellaneous Gram-negative organisms. The DRT's of the 91 *Salmonella* cultures ranged from 0.48 to 0.91 minute in liquid egg, and 0.45 to 0.69 minute in tryptose broth. In general, differences in the DRT's were not marked, and little relationship could be noted between their magnitudes and specific strains, types or species within a given genus. Many individual strains, moreover, revealed remarkably constant

DRT's, provided that care was taken to ensure uniform test conditions as well as uniform treatment of culture prior to the test. This was noted particularly from repetitive observations made on different days. The DRT's of 40 *Salmonella* cultures calculated from 2 heating times at the same temperature generally showed good agreement. For example, the DRT's of several strains (one each of *S. tennessee, S. bareilly, S. newport, S. derby*) calculated from the number of survivors of 3 minutes of heating at 58° were 0.72, 0.85, 0.82 and O.62, respectively. The DRT's of the same cultures calculated from the number of survivors of 4 minutes of heating at the same temperature were 0.79, 0.84, 0.79 and 0.63, respec-

TABLE 1

Decimal Reduction Times at 58° C. of Salmonella and Other Gram-Negative Organisms Suspended in Liquid Whole Egg and in Tryptose Broth[1]

Organism	Number of strains tested	Decimal Reduction Time (DRT) (minutes) in	
		Liquid whole egg	Tryptose broth
S. oranienburg	12	.54-.83	.46-.54
S. montevideo	10	.55-.88	< .46-.60
S. tennessee	6	.53-.79	< .45-.69
S. bareilly	1	.83	
S. georgia	1	.64	
S. thompson	1	.63	
S. oslo	1	< .49	
S. newport	4	.63-.82	
S. manhattan	1	.51	
S. typhimurium	10	.61-.84	.48-.59
S. paratyphi B	2	.80-.91	.47-.53
S. derby	4	.56-.62	
S. california	1	.58	
S. bredeney	1	.63	
S. anatum	7	.58-.84	< .46-.52
S. senftenberg	11	.56-.84	.49-.59
S. london	3	.68-.76	.48-.49
S. newington	2	.48-.59	
S. cerro	2	.68-.76	
S. poona	1	.74	
S. madelia	1	.77	
S. kentucky	1	.57	
S. panama	2	.65-.73	
S. pullorum	6	.52-.68	
Paracolon sp	7	< .49-.62	
Aerobacter sp	6	.50-.56	
Pseudomonas sp	4	< .49-.51	
E. coli	4	.56-.92	

[1] All the organisms except two strains of *E. coli* were isolated from spray-dried whole-egg powder.

tively. Where there were comparative data, a lower range of DRT's was obtained for the cultures grown and tested in tryptose broth than in liquid egg. This was demonstrable not only when the DRT's were tested in the two media on different days but also when tested simultaneously in the same trial run.

Four cultures, one each of *S. oranienburg* and *S. senftenberg* and two of *S. paratyphi B*, gave indications of being more heat-resistant than the remaining test cultures, since more than 10 percent of the cells survived the heating period of 3 minutes at 58° C. The DRT's for these cultures at a higher temperature, 61°, were as follows: *S. oranienburg*, 0.66 minute in liquid egg, 0.59 minute in tryptose broth; *S. senftenberg*, 1.11 minutes in liquid egg, 1.19 minutes in tryptose broth;

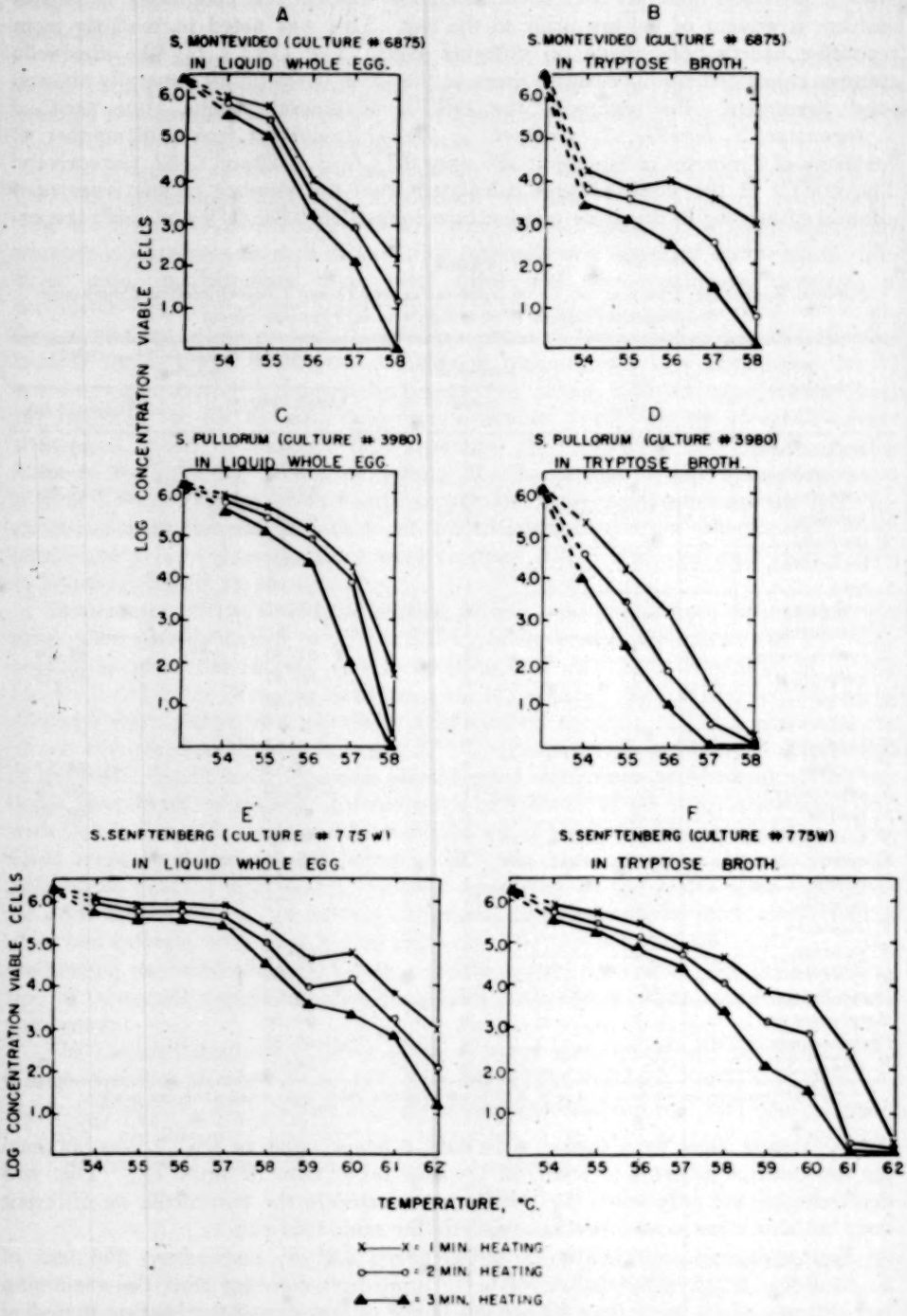

FIG. 1. Effect of heat treatment on viability of *Salmonella* organisms suspended in liquid whole egg and tryptose broth.

one *S. paratyphi B* strain, 0.85 minute in liquid egg, 0.91 minute in tryptose broth; the other *S. paratyphi B* strain, 0.83 minute in liquid egg, 0.69 minute in tryptose broth. The resistant *S. senftenberg* strain was one of the four used in the heat-resistant mix reported by Winter et al. *(11)*. Two others of the four strains available to us either failed to retain their heat-resistant characteristics or were not demonstrable by this method.

The DRT's in liquid egg for the cultures representing paracolons, *Aerobacter, Pseudomonas,* and *E. coli* (Table 1) fell between 0.49 and 0.62 minute, with the exception of one *E. coli* strain from egg powder, which had a DRT of 0.92.

Figure 1 (A-F) presents graphically the effect of different heating times and temperatures on the survival of *Salmonella* organisms in liquid egg and in tryptose broth. It illustrates the results obtained with 11 cultures studied at temperatures ranging from 54° to as high as 62° C. Sections (A) and (B) typify curves obtained with *S. oranienburg, S. montevideo, S. tennessee, S. london,* and *S. newport;* sections (C) and (D), the curves obtained with *S. pullorum;* and sections (E) and (F), the curves obtained with the heat-resistant strain of *S. senftenberg.* As may be noted, in general, greater destruction occurred in tryptose broth than in liquid egg. Also, differences between the individual cultures in their resistance to destruction by heat are illustrated by variations in the slopes of the respective survival curves. Variations in the curves, however, are not of sufficient magnitude to indicate that it would be impractical to reduce the viable *Salmonella* organisms in liquid whole egg by a pasteurization process.

DISCUSSION

The results show that on the whole, as determined by the methods employed in this study, there is little variation in the DRT's of the different *Salmonella* types and strains. Only 4 strains gave evidence of being more resistant to heat than the other 91. The 21 cultures of Gram-negative organisms representing known contaminants of liquid whole egg (paracolon, *Aerobacter, Pseudomonas, E. coli*) had DRT's of similar magnitude as the *Salmonella* strains. In most instances, heating at 58° C., a temperature 2° (3.6° F.) below that recommended in Quartermaster Corps Tentative Specification, C. Q. D. 117B (1944), was sufficient to reduce 1 to 3 million cells to less than 0.1 percent of the original concentration in 0.48 to 0.92 minute. The demonstrated effectiveness of heat in reducing the number of viable vegetative cells in liquid egg further substantiates observations made by Greco *(2)*, Winter et al. *(12)*, Gibbons et al. *(1)*, Schneider *(8, 9)*, Wilkin and Winter *(10)*. Since the concentrations of young actively growing cells used in making the DRT determinations were in excess of what might be expected in commercially processed liquid whole egg, it may reasonably be assumed that flash pasteurization at 60° should reduce the number of *Salmonella,* when present, to a marked degree.

SUMMARY

The Decimal Reduction Times of 95 *Salmonella* cultures, representing 24 types, and 21 other Gram-negative cultures were determined in liquid whole egg and tryptose broth. All the cultures with the exception of two *E. coli* strains were isolated from egg powder. The DRT's for all the organisms tested, except for one strain each of *S. oranienburg* and *S. senftenberg* and two strains of *S. paratyphi B,* were less than one minute at 58° C. The DRT's for these four cultures determined at 61° ranged from 0.66 to 1.11 minutes in liquid egg, and from 0.59 to 1.19 minutes in tryptose broth.

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MICROBIOLOGY OF SPRAY-DRIED WHOLE EGG
IV. MOLDS [a]

ALICE J. WATSON AND VERNON H. McFARLANE
Microbiology Research Division, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture

This paper presents information relating to factors concerned in mold contamination of spray-dried whole-egg powder. Seasonal variation of contamination and types of molds encountered in a study of more than six thousand egg powder samples are discussed together with data on comparative growth of different molds as a function of incubation temperature.

Examination of high-moisture (4to6%) spray-dried whole-egg powder for molds was undertaken in 1943-1944 simultaneously with examinations for plate and direct counts *(5)*, for incidence and types of *Salmonella (7)*, and for *Escherichia coli (8)*. The findings presented in this paper are concerned with the overall incidence of mold in the egg powder, with the seasonal variations in incidence, with the kinds of molds isolated, and with their comparative rates of growth at 24° C. (75.2° F.) to 55° C. (131° F.).

PROCEDURE

Plate counts. Serial dilutions of each egg powder sample were plated on wort agar,[b] pH 4.6 ± 0.1. Plates were incubated for three days at 30° C. (86° F.). Counts of less than 100 per gram were not recorded. Since the United States Department of Agriculture and War Food Administration Purchase Specifications (1943-1944) did not include a tentative standard for mold counts, an arbitrary maximum count of 1000 per gram was selected. This figure, which was partially based on field experience, allowed considerable tolerance for existing plant operating conditions. Egg powder samples with mold counts of 1000 per gram and higher are referred to in this paper as high-count samples.

Identification. Most of the mold cultures selected for identification represented single isolations made from high-count samples. Isolated colonies were picked from wort agar plates and further purified by the serial dilution poured-plate technic. Multiple spore heads picked from isolated colonies appearing on the second series of plates were transferred to slants. Identifications in this laboratory were made from Czapek-Dox agar containing 3 percent sucrose, pH 7.0 ± 0.1. Representative cultures were sent to Dr. Kenneth B. Raper, Northern Regional Research Laboratory [c] for confirmation or identification.

Rates of Growth of Mold Mycelial Discs. Rates of growth at different temperatures have been expressed in terms of mean daily diameter increments (MDDIs) of the mycelial discs in millimeters per 24 hours following the method of Fawcett *(1)*. Mean daily diameter increments were determined for each of several identified molds, principally for those isolated from high-count egg powders. Measurements

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[a] This investigation was carried on in cooperation with the Poultry Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington, D. C. The samples of egg powder examined represented U.S.D.A. lots manufactured for Lend-Lease shipment.

[b] One hundred grams of commercial malt sirup and 15 grams of agar per liter of distilled water were used in the preparation of the medium. This formula is the same as the one given by Berry (J. Bact. 26:459, 1933) except for the substitution of distilled for tap water. However, the ingredients were dissolved and sterilized after the manner of Smith and Raistrick (An Introduction to Industrial Mycology. Edward Arnold & Co., Ltd., London, England. 2d Ed., 170, 1942).

[c] 825 N. University Street, Peoria 5, Illinois.

were made of the growths occurring on Czapek-Dox (3% sucrose, pH 7.0 ± 0.1), wort (pH 4.6 ± 0.1), and tryptone-glucose-extract (pH 7.0 ± 0.2) agar plates incubated at 24° C. (75.2° F.), 30° C. (86° F.), 37° C. (98.6° F.), 45° C. (113° F.), and 55° C. (131° F.). Rates of growth (MDDIs) were also determined on an egg-agar medium [4] at 24°, 30°, 37° and 45° C. for single egg-powder isolates of *Aspergillus flavus* Link, *A. fumigatus* Fres., a *Penicillium luteum* group member, *P. frequentans* West., *Rhizopus arrhizus* Fischer, and a *Mucor* species. Of the four mold cultures introduced into the study for comparison purposes, one, *A. flavus* Link (ATCC No. 9807), was obtained initially from the American Type Culture Collection [5] and three, *A. sydowi* (Bain. and Sart.) Thom and Church (NRRL No. 247), *P. oxalicum* Currie and Thom (NRRL No. 789), and *P. chrysogenum* Thom (NRRL No. 807), were obtained from the Northern Regional Research Laboratory Collection.

The procedure followed in determining the MDDIs for each mold was patterned after Fawcett's. The seeding technic, however, differed. A heavy spore suspension of a given mold in physiological saline was prepared from a 10-day Czapek-Dox slant. A small drop of this suspension was transferred from a 1-ml. pipette to the center of a poured agar plate by touching the tip of the pipette to the surface of the agar. Two plates made for each set of conditions were allowed to stand at room temperature for 4 to 6 hours. Then the areas of inoculation were measured and the plates placed at the different temperatures. Czapek-Dox plates were incubated for 5 days. At the end of this period, two different diameters of each mycelial disc were measured and averaged. The MDDI was then determined for each mold by subtracting the average diameter (in mm.) of the areas of inoculation from the average diameter (in mm.) of two mycelial discs and dividing the remainder by the number of days of incubation, in this instance 5 days. A few molds grew so rapidly on wort agar that their MDDIs on this medium had to be calculated at 2- to 3-day incubation intervals. Fawcett *(1)* has pointed out that the magnitude of the mean rate of enlargement of the mycelial discs " . . . is influenced by the variations in at least three conditions for any one organism, namely, (1) the degree of maintained temperature, (2) the length of the time period considered in deriving the mean rates, and (3) the time relation of any given observation period to the beginning of the entire culture period."

INCIDENCE OF MOLD IN EGG POWDER

Of the 6,521 samples of spray-dried whole-egg powder examined, 2,341 (36%) had mold counts of 100 or higher per gram. Only 86 of these (1.3%) had counts of 1,000 or higher. The counts ranged to 41,000.

By months. Table 1 shows a seasonal variation in the monthly incidence of mold contamination in samples. In 1944 the percentage of samples contaminated with molds (100 or higher per gram) decreased from 34 percent in January to 20 percent in April and then increased to 47 percent in December. In 1943 the percentages of samples contaminated with molds in September through December were even greater than for the corresponding months in 1944.

By plants. The incidence of mold contaminated egg powder samples received from 101 individual dehydration plants ranged from 0 to 93 percent. However, the six plants with the zero incidence forwarded 14 or fewer samples each.

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[4] An egg medium (pH 7.7) was prepared which contained 75 grams of dried whole egg and 10 grams of agar per liter of distilled water. The ingredients were dissolved separately, mixed while warm and dispensed in petri dishes. These were covered with porcelain tops and sterilized at 15 pounds pressure for 15 minutes.

[5] Georgetown University School of Medicine, 3900 Reservoir Road, N. W., Washington 7, D. C.

TABLE 1

Incidence of Mold in Egg Powder Samples, by Months

Month	Number plants contributing samples	Number samples examined	Number of samples which had plate counts of—	
			100 or more per gram	1000 or more per gram
1943			*percent*	
September	15	138	70 (50.7)	7
October	31	226	120 (53.1)	9
November	30	327	161 (49.2)	5
December	30	219	121 (55.2)	9
1944				
January	68	443	152 (34.3)	6
February	78	669	222 (33.2)	9
March	61	518	121 (23.3)	3
April	64	531	106 (20.0)	5
May	67	565	143 (25.3)	5
June	68	566	175 (30.9)	7
July	63	523	203 (38.8)	6
August	65	605	231 (38.2)	4
September	63	472	201 (42.6)	6
October	59	372	161 (43.3)	1
November	39	217	93 (42.8)	3
December	26	130	61 (46.9)	1
Total	101	6521	2341 (35.9)	86 (1.3)

The 86 high-mold count samples originated in 34 dehydration plants. A single mold was predominant in each, usually to the exclusion of others, but the same mold did not predominate in every high-mold count sample received from the same plant. This observation was made for 5 of the 21 plants which forwarded 2 to 7 high-mold-count samples each. Of six such samples forwarded by Plant No. 6 over a seven-month period, *A. flavus* was isolated from the first, second, third, fifth, and sixth, and *A. chevalieri* var. *intermedius* Thom and Raper was isolated from the fourth. *A. chevalieri* var. *intermedius* was also isolated from the third sample and a *Mucor* species from the sixth.

Table 2 gives data for 43 plants which forwarded 50 or more samples. Fifty percent or more of the samples contributed by seven of the plants had mold counts of 100 per gram or higher.

By U. S. Divisions. The incidence of mold in egg powder samples received from the East North Central, West North Central and South Central Divisions of the United States is given in Table 3. The South Central Division had the highest percentage of mold-contaminated samples. Incidence data for the North Atlantic, South Atlantic and Western Divisions were combined because of the few samples received from these Divisions, and the few *(6)* states represented.

MOLDS ISOLATED FROM EGG POWDER

The predominant mold isolated from each of the 86 high-mold-count egg powders is listed in Table 4. As may be noted, 60 of the 77 identified isolates were *Aspergilli;* 52 belonged to the *A. flavus* Link group.

Molds were occasionally isolated from samples of egg powder whose counts were less than 1,000 per gram. Among those identified were: *P. chrysogenum* Thom, *P. frequentans* West., *P. steckii* Zal., *P. purpurogenum* Stoll, *P. martensii* Biourge, members of the *P. notatum-chrysogenum* group, *A. versicolor* (Vuill.) Tira., *A. amstelodami* (Mang.) Thom and Raper, *A. tamarii* Kita, and members of the *A. glaucus* group.

TABLE 2

Incidence of Mold in Egg Powder Samples, by Plants

Plant No.	Number samples examined	Number of samples which had plate counts of—	
		100 or more per gram	1000 or more per gram
		percent	
1	88	18 (20.5)	0
2	210	95 (45.2)	0
3	62	30 (48.4)	1
4	50	26 (52.0)	1
5	86	27 (31.4)	0
6	258	117 (45.3)	6
7	52	25 (48.1)	2
8	59	24 (40.7)	1
9	60	22 (36.7)	1
10	72	6 (8.3)	0
11	91	54 (59.3)	4
12	65	32 (49.2)	1
13	601	246 (40.9)	2
14	121	66 (54.5)	4
15	78	15 (19.2)	0
16	93	40 (43.0)	5
17	206	28 (13.6)	0
18	155	20 (12.9)	0
19	87	36 (41.4)	4
20	74	33 (44.6)	1
21	219	75 (34.2)	1
22	177	35 (19.8)	0
23	119	45 (37.8)	0
24	240	58 (24.2)	1
25	236	107 (45.3)	3
26	79	34 (43.0)	0
27	179	105 (58.7)	0
28	133	38 (28.6)	0
29	96	14 (14.6)	0
30	123	46 (37.4)	0
31	66	38 (57.6)	2
32	99	32 (32.3)	3
33	55	39 (70.9)	2
34	90	22 (24.4)	0
35	54	50 (92.6)	7
36	55	8 (14.5)	0
37	166	36 (21.7)	1
38	57	12 (21.1)	0
39	72	10 (13.9)	0
40	75	25 (33.3)	2
41	70	32 (45.7)	5
42	87	22 (25.3)	0
43	98	37 (37.8)	0

RATES OF GROWTH OF MOLD MYCELIAL DISCS

Table 5 shows the mean daily diameter increments for several molds grown on Czapek-Dox medium at 24°, 30°, 37° and 45° C. None of the molds listed grew on Czapek-Dox at 55°. All grew at 24° and all but one culture, a strain of *A. chevalieri* var. *intermedius*, at 30°. Nine cultures incubated at 37° and 17 incubated at 45° did not show any macroscopic evidence of growth in 5 days.

Most species exhibited a different MDDI at each temperature at which growth occurred. Also, different species generally exhibited different MDDIs at the same

TABLE 3

Incidence of Mold in Egg Powder Samples Received from Divisions of the United States

Divisions	Number plants contributing samples	Number samples examined	Number of samples which had plate counts of—	
			100 or more per gram	1000 or more per gram
			Percent	
East North Central (Ohio, Ind., Ill., Mich. and Wis.)	26	1718	602 (35.0)	18
West North Central (Minn., Iowa, Mo., N. Dak., S. Dak., Nebr. and Kans.)	40	1915	533 (27.8)	19
South Central (Ky., Tenn., Ala., Miss., Ark., La., Okla. and Texas)	25	2314	1001 (43.3)	42
North Atlantic, South Atlantic and Western	10	574	205 (35.7)	7
Total	101	6521	2341 (35.9)	86

TABLE 4

Predominant Mold Isolated from Each of 86 Samples of Egg Powder Which Had Counts of 1,000 per Gram or Higher

Molds	Number times isolated
Aspergillus flavus Link group	52
Penicillium species	5
Aspergillus species	3
Mucor species	3
Chaetomium globosum Kunze	3
Penicillium luteum group	2
Rhizopus species	2
Aspergillus terreus Thom	1
Aspergillus fumigatus Fres	1
Aspergillus nidulans (Eidam) Wint	1
Aspergillus chevalieri var. *intermedius* Thom and Raper	1
Aspergillus sydowi (Bain. and Sart.) Thom and Church	1
Alternaria species	1
Oidium species	1
Unidentified	9
Total	86

temperature. The greatest MDDIs recorded for the two strains of *P. chrysogenum*, 3.4 and 3.8 mm., respectively, were obtained at 24° C. There were a few isolates whose MDDIs at 30° were slightly greater than at 24°. There were other isolates whose MDDIs were definitely greater at the higher temperature, i. e., *A. nidulans* (Eidam) Wint., *A. tamarii, A. flavus, A. fumigatus, A. terreus* Thom, and the two *Mucor* species. The highest MDDI values recorded for *A. fumigatus* (15.4 mm.), for *A. nidulans* (11.6 mm.), for *R. arrhizus* (15.4 mm.), and for *Mucor varians* Povah (?) (14.4 mm.) were obtained at 37°. The highest recorded for the *Mucor* species (17.2 mm.) was at 45°.

The MDDIs obtained when the molds were cultured on tryptone-glucose-extract agar were of a magnitude similar to those obtained on Czapek-Dox medium for a given incubation temperature. Growth on wort agar was generally greater than on

TABLE 5

Comparative Mean Daily Diameter Increments of Molds Incubated at 24°, 30°, 37° and 45° C.

Molds	MDDI [1] of mycelial disc, mm. per 24 hours at —				Number of strains from which mean was obtained
	24° C. (75.2° F.)	30° C. (86° F.)	37° C. (98.6° F.	45° C. (113° F.)	
ISOLATED FROM EGG POWDER					
Aspergillus flavus Link group	5.8	8.8	6.8	0.3	14
Aspergillus fumigatus Fres	7.6	11.7	15.4	9.6	4
Aspergillus nidulans (Eidam) Wint	5.7	8.1	11.5	3.9	1 [2]
Aspergillus terreus Thom	2.8	5.0	5.0	1.6	1
Aspergillus sydowi (Bain. and Sart.) Thom and Church	1.9	2.1	0.1	0	3
Aspergillus tamarii Kita	6.2	9.0	2.4	0	1
Aspergillus glaucus group	1.6	2.0	0	0	1 [2]
Aspergillus amstelodami (Mang.) Thom and Raper	1.1	1.4	0	0	1 [2]
Aspergillus chevalieri (Mang.) Thom and Church	2.6	2.0	0	0	1
Aspergillus chevalieri var. *intermedius* Thom and Raper	0.9	1.0	0	0	2 [2]
Penicillium chrysogenum Thom	3.4	1.8	0	0	1
Penicillium luteum group	1.0	1.4	1.2	0	1
Penicillium species	0.6	0.7	0	0	1 [2]
Penicillium frequentans West	2.4	2.8	0.8	0	1
Rhizopus arrhizus Fischer	13.8	14.0	15.4	5.8	2
Mucor varians Povah (?)	5.6	11.0	14.4	9.6	2
Mucor species	4.2 (?)	10.2	16.6	17.2	1 [2]
OBTAINED FROM ATCC [3] AND NRRL [4] COLLECTIONS					
Aspergillus flavus Link (ATCC No. 9807)	7.2	8.9	9.2	0	1
Aspergillus sydowi (Bain. and Sart.) Thom and Church (NRRL No 247)	2.2	2.2	0	0	1
Penicillium oxalicum Currie and Thom (NRRL No. 789)	6.2	6.0	1.6	0	1
Penicillium chrysogenum Thom (NRRL No. 807)	3.8	0.8	0	0	1

[1] MDDI = Mean daily diameter increments determined on Czapek-Dox (3% sucrose) plates and calculated on 5-day incubation period.

[2] MDDI = Average of determinations made with duplicate cultures of the same strain.

[3] ATCC = American Type Culture Collection, Georgetown University School of Medicine, 3900 Reservoir Road, N. W., Washington 7, D. C.

[4] NRRL = Northern Regional Research Laboratory Collection, Northern Regional Research Laboratory, Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, 825 N. University Street, Peoria 5, Illinois.

either of the other two media. For example, the MDDIs as determined on wort agar for the 14 strains of *A. flavus* (Table 5) were, for the four temperatures, 9.6 mm., 12.7 mm., 8.8 mm. and 0.3 mm., respectively.

The egg agar did not appear to be any more favorable than Czapek-Dox for the growth of the *A. flavus* and *A. fumigatus* strains tested. It did favor the growth of the *P. luteum* group member and *P. frequentans* to the extent that their MDDIs were approximately double those obtained on Czapek-Dox and even exceeded those obtained on wort. *R. arrhizus* grew much more rapidly on egg agar than on Czapek-Dox. This species overgrew the egg agar plates in 2 days at 30° and 37° C. It also overgrew the wort agar plates in 2 days at 24° and 30°. The *Mucor* species grew equally well on the egg, Czapek-Dox and wort agars at 24° and 30°. At 37° its MDDI (3-day) was greatest on the egg agar. The two *Penicillia* grew better at

37° on the egg agar than on any of the other three agars. However, the question of whether one medium might be better suited than another for the growth of a given mold species at 37° or 45° was not further investigated. Of the six isolates employed, only *A. fumigatus* strain grew on egg agar at 45°.

DISCUSSION

Although 36 percent of the egg powder samples had mold counts of 100 or more per gram, only 1.3 percent had counts of 1000 and over. This, the authors feel, is a good record, considering the war emergency conditions with which the egg dehydration industry had to contend at the time.

Comparison of data in Table 1 with United States Department of Agriculture figures on the monthly production of dried egg from fresh shell, storage shell and frozen egg (1943-1945) showed a direct relationship between incidence of mold in samples and the kind of liquid egg dried. That is, the percentages of samples contaminated with mold were highest in months in which the highest percentages of storage shell and frozen egg liquid had been dried. Similar correlations were noted in comparisons of the kind of liquid egg dried with the monthly plate count averages *(5)* and the incidence and degree of *E. coli* contamination *(8)*.

From a regional standpoint, the generally warmer temperatures and higher humidities prevailing in the more southern states may account for the higher incidence of mold contamination noted in the egg powder samples received from the South Central Division than in the samples received from the two more northerly Midwestern Divisions, other factors being the same.

No endeavor was made in this study to determine the relative distribution of mold species in the 2,341 mold-contaminated egg powder samples, but it was observed (Table 4) that the *Aspergilli* were predominant in the 86 samples which had counts of 1000 per gram or higher. Both *Aspergilli* and *Penicillia* are widespread in nature and common in soil *(9, 10)*. Molds of the latter group have been the more commonly associated with shell eggs originating in the producing areas which supplied the expanded 1943-1944 egg dehydration industry *(2, 3, 6)*. Hence, the predominance of the *Aspergilli* in the high count powders may be attributable to the action of selective environment within the dehydration system. The MDDI values, Table 5, lend partial support to this thought. They were generally higher for the *Aspergilli* than for the *Penicillia* at the temperatures investigated. On the other hand, they were also high for the infrequently occurring *Rhizopus* and *Mucor* species. Mold growths have been observed *(4)* in units of dehydration systems where temperature-humidity conditions were favorable. Unfortunately, at the time their field observations were made data were not recorded as to the kind of molds or as to the exact temperature and moisture content of the egg substrate in which the molds were growing in the dehydration units. It was observed, however, that when mold counts in powder sampled at the time of barrelling approached 1000 per gram or higher it was often possible to trace through the units of the system immediately following a shut-down and detect macroscopically the area or areas in which molds were developing and feeding into the powder. Ten such areas are listed in the above reference. There is no intent to infer, however, that molds in liquid egg could not escape the destructive action of the heat in the primary drying chamber.

Powders heavily seeded with mold are likely to spoil rapidly if packaged in containers which permit the passage of air and moisture. This and other facts pertinent to the significance of molds in egg powder have been discussed by the authors in the reference cited. It appears improbable that a mold-free egg powder could be consistently produced under operating conditions like those which were commonly practiced in 1943-1944 in the manufacture of high-moisture (4 to 6%),

spray-dried whole-egg powder. Although all the contaminated samples examined in this study were organoleptically acceptable insofar as the effect of mold contamination could be determined, this observation does not justify tolerance of high-count powders. It is evident that high-count powders were manufactured from highly contaminated liquid egg and/or that molds developed in moist powders within the dehydration systems.

SUMMARY

Of 6,521 samples of high-moisture (4 to 6%) spray-dried whole-egg powder, 2,341 (36%) had mold counts of 100 or higher per gram. Only 86 (1.3%) had counts of 1,000 or higher. The incidence of mold in samples varied with the season of the year and with individual dehydration plants. A higher percentage of samples containing mold was received from the South Central Division of the United States than from either of the other two Midwestern Divisions.

The *Aspergilli* were the molds most frequently encountered in the high-mold-count (1,000 or more per gram) egg powders.

Rates of growth of the mold mycelial discs varied according to the mold, the medium, and the incubation temperature. Although members of the *A. flavus* Link group made up more than half the isolates from high-mold-count egg powders, there were others—*A. fumigatus* Fres., *A. nidulans* (Eidam) Wint. and the *Rhizopus* and *Mucor* species—whose mean daily diameter increments were generally greater under the conditions tested, particularly at 37° and 45° C.

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A STUDY OF THE GERMICIDAL VALUE OF GLYCOLS, GLYCOL BENZOATES, AND RELATED COMPOUNDS

HAROLD C. HEIM AND CHARLES F. POE*
College of Pharmacy and Department of Chemistry
University of Colorado, Boulder

Studies are reported of the germicidal powers of glycols, glycol benzoates, esters of benzoic acids, and related compounds. Besides cultures of S. aureus and E. typhi, those of E. coli, A. aerogenes, and S. cerevisiae were used. The majority of the compounds studied fail to show any marked germicidal properties. Alcoholic fermentation was largely inhibited by some of the compounds, especially the propylene glycol esters, and aliphatic alcohol esters of the benzoates.

INTRODUCTION

From the analysis of a number of food products, it has been revealed that propylene glycol and certain esters of hydroxybenzoic acids have been used as food preservatives. This fact suggested the present research in order to study the ability of glycols, glycol benzoates, esters of benzoic acids, and related compounds to inhibit or prevent the growth of microorganisms. Several glycol benzoates previously have been prepared in this laboratory, Heim and Poe *(4)*.

The esters of *p*-hydroxybenzoic acid are prepared on a commercial scale by at least two manufacturing companies and are advertised as being effective as preservatives in neutral, acidic, or moderately alkaline media. Propylene glycol has appeared in food and drug products as a constituent designed to serve as a preservative for ground meats, pastries, milk, cosmetics, and other products. Ethylene glycol has been advocated as a preservative in certain types of drug preparations, but its use has been quite limited because of its high toxicity.

Benzoic and salicylic acids have long been used as food preservatives. Sabalitschka, Dietrich, and Bohn *(13)* studied the various substituted benzoic acids with respect to their inhibitory properties. These authors found that benzoic and salicylic acids exerted more preservative action than their methyl or ethyl esters, but that the reverse was true with the *m*- and *p*-hydroxybenzoic acids.

Velthorst *(17)* conducted a study of the preservative properties of certain *p*-hydroxybenzoic acid esters and concluded that these esters could not be considered as ideal preservatives. He further stated that there was no justification for their use in place of benzoic acid. Sabalitschka *(14)*, however, concluded that small quantities of *p*-hydroxybenzoic acid esters were effective preservatives. Freund *(2)* investigated the toxicities of the ethyl and propyl esters of *p*-hydroxybenzoic acid by feeding oil emulsions of the esters to rabbits. He concluded that the esters were essentially less toxic than the hydroxybenzoic acids and, therefore, were more suitable for use as food preservatives. Karsmark *(8)* compared the preservative properties of certain esters of *p*-hydroxybenzoic acid and phenol. He found that the methyl and ethyl esters of *p*-hydroxybenzoic acid were from two to three times more effective than benzoic acid in inhibiting bacterial growth. Tilgner and Schillak *(16)* compared the relative efficiency of various *p*-hydrobenzoic acid esters as preservatives. These authors reported that the ethyl ester was most effective and had no effect on the taste of the preserved medium; whereas, the methyl ester produced an undesirable effect on taste and exhibited but slight preservative action.

* For reprints address the junior author, University of Colorado.

The use of the glycols as preservatives has been of recent introduction, although as early as 1905 ethylene glycol monosalicylate was being manufactured in Germany under the name of "Spirosal" and used in the treatment of gout and rheumatism, Ruheman *(12)*. Rae *(10)* studied the preservative properties of ethylene and propylene glycols. He found that both of these glycols were superior to ethyl alcohol and glycerol in the preservation of tannic acid solutions. It was further reported that in order to preserve sucrose solutions, a concentration of 10 per cent of either ethylene glycol or propylene glycol was required.

Within the past ten years the toxicities of certain of the glycols have been extensively studied. Hunt *(6)* reported that ethylene glycol was as toxic as methyl alcohol, and that its toxicity was caused by the fact that it was converted into oxalic acid in the body. He further showed that propylene glycol was not toxic when fed to rats. Hanzlik *(3)* concluded that ethylene glycol was not so toxic as indicated by the results of the preceding investigation; but Hunt *(7)*, in a subsequent publication, cited further evidence in support of the belief that ethylene glycol was as toxic as methyl alcohol. Seidenberg and Hanzlik *(15)* reported that the symptoms of toxicity of propylene glycol for rats and rabbits were evidenced by a general motor depression and an increased respiratory rate. Intravenous fatal doses were reported to be 16.8 mg. per kg. for rats and 5.25 mg. per kg. for rabbits. From these results the authors concluded that propylene glycol was less toxic than ethylene glycol and offered the same advantages. Braun and Cartland *(1)* investigated the toxicity of propylene glycol. The results showed a minimum lethal dose of 15.7 gm. per kg. when administered subcutaneously; whereas oral doses of 8 cc. per day produced no harmful effects. Holck *(5)* reported on the toxicities of ethylene glycol, glycerol, diethylene glycol, and propylene glycol. This author concluded that when glycerol was added to the food of rats in concentrations as high as 20 per cent, no harmful effects were noted. He observed, however, that the glycols produced toxic effects when small quantities were added to the drinking water of the animals. Weatherby and Haag *(18)* reported that the acute, average, fatal dose of propylene glycol when administered orally to rats was 33.5 grams per kilogram. Poe and Witt *(9)* made a study of the toxicity of ethylene glycol for white rats. They found the toxic dose to be 12,500 mg. per kg. when administered intraperitoneally.

METHODS AND PROCEDURE

In order to determine the germicidal properties of the glycols, acids, and esters, the method outlined by Ruehle and Brewer *(11)* was used. This method is recognized by the United States Food and Drug Administration as the official method for testing antiseptics. The relative germicidal power of each compound is expressed by its phenol coefficient, which is a value showing the ratio of the germicidal efficiency of each substance against a test organism to that of phenol tested under the same conditions. *Eberthella typhi* and *Staphylococcus aureus* were selected as the test organisms. Saturated solutions of all compounds, except the glycols, were made in sterile distilled water. Tests for germicidal activity were run on dilutions of these solutions. The glycols were miscible with water in all proportions.

The extreme insolubility of the esters in water led to the study of their germicidal power in an alcohol and water mixture, which in itself possessed no germicidal power for the test organisms, but which would dissolve more of the ester than distilled water. Alcohol and water were mixed in different proportions and the germicidal power of each solution was obtained. When an alcohol-water mixture was found which did not kill the organisms in 15 minutes, it was used as a solvent for the esters.

In addition to testing the germicidal properties of the acids, esters, and glycols, the power of these compounds to inhibit the growth of common non-pathogenic organisms and to prevent or inhibit alcoholic fermentation was studied. The non-pathogenic bacteria selected were *Escherichia coli* and *Aerobacter aerogenes*. A culture of yeast, *Saccharomyces cerevisiae*, was selected as the test organism by which to study the effect of the different compounds on alcoholic fermentation.

In order to determine the efficiency of the acids and esters as inhibitors for *E. coli* and *A. aerogenes*, enough of each compound was added to lactose broth contained in fermentation tubes to saturate the broth. Then 0.1 cc. of a 24 hour culture of the test organism was added to each tube by means of a sterile pipette and the tubes incubated at 37° C. After 12, 24, 48, and 72 hours, each tube was examined for growth and gas production. The same procedure was followed in studying the effect of the acids and esters on alcoholic fermentation, except that dextrose broth was used in place of lactose broth and *S. cerevisiae* was used as the test organism.

The glycols, being miscible in all proportions with the broth used, were added to the broth in definite amounts so that known dilutions were obtained. Exactly 10 cc. of broth were placed in each of the tubes.

Few foods, drugs, or cosmetics are found which have a hydrogen ion concentration corresponding to neutrality. Because of this fact, it was decided to test the inhibitory effects produced by the acids and esters in media adjusted to different pH values. Experiments were carried out as before, with *E. coli* and *A. aerogenes* as test organisms, in media having pH values of 5.8, 7.0, and 8.9. Since the optimum value of pH for the growth of yeast is in the vicinity of 4.8, the medium was adjusted to this value, and *S. cerevisiae* was used as the test organism.

EXPERIMENTAL RESULTS

Table 1 shows the phenol coefficients of the different glycols when *S. aureus* and *E. typhi* were used as the test organisms. The phenol coefficients of some of the benzoic acids are reported in Table 2.

Saturated aqueous and saturated 30 per cent alcoholic solutions of the following esters were tested with both organisms: methyl benzoate, methyl salicylate, methyl *m*-hydroxybenzoate, methyl *p*-hydroxybenzoate, ethyl benzoate, ethyl salicylate,

TABLE 1

Phenol Coefficients of the Glycols

Compound	*S. aureus* Phenol Coefficients	*E. typhi* Phenol Coefficients
Ethylene glycol	0.0	0.012
Diethylene glycol	0.0	0.012
Propylene glycol	0.021	0.018
Trimethylene glycol	0.0	0.0

TABLE 2

The Phenol Coefficients of Some Benzoic Acids

Compound	*S. aureus* Phenol Coefficients	Average	*E. typhosa* Phenol Coefficients	Average
Benzoic acid	0.0, 0.0	0.0	5.1, 5.7	5.4
Salicylic acid	9.6, 10.4	10.0	10.4, 11.2	10.8
m-hydroxybenzoic acid	1.4, 1.7	1.5	2.1, 2.3	2.2
p-hydroxybenzoic acid	0.0, 0.0	0.0	0.0, 0.0	0.0
o-chlorobenzoic acid	0.0, 0.0	0.0	7.6, 8.0	7.8
m-chlorobenzoic acid	0.0, 0.0	0.0	0.0, 0.0	0.0
p-chlorobenzoic acid	0.0, 0.0	0.0	0.0, 0.0	0.0

ethyl *m*-hydroxybenzoate, ethyl *p*-hydroxybenzoate, propyl benzoate, propyl salicylate, propyl *m*-hydroxybenzoate, propyl *p*-hydroxybenzoate, butyl benzoate, butyl salicylate, butyl *m*-hydroxybenzoate, butyl *p*-hydroxybenzoate, ethylene glycol dibenzoate, ethylene glycol disalicylate, ethylene glycol di-*o*-chlorobenzoate, ethylene glycol di-*m*-chlorobenzoate, ethylene glycol di-*p*-chlorobenzoate, trimethylene glycol dibenzoate, trimethylene glycol disalicylate, trimethylene glycol di-*o*-chlorobenzoate, trimethylene glycol di-*m*-chlorobenzoate, trimethylene glycol di-*p*-chlorobenzoate, propylene glycol dibenzoate, propylene glycol disalicylate, propylene glycol di-*o*-chlorobenzoate, propylene glycol di-*m*-chlorobenzoate, propylene glycol di-*p*-chlorobenzoate, diethylene glycol dibenzoate, diethylene glycol disalicylate, diethylene glycol di-*o*-chlorobenzoate, diethylene glycol di-*m*-chlorobenzoate, diethylene glycol di-*p*-chlorobenzoate, ethylene glycol monobenzoate, ethylene glycol monosalicylate, ethylene glycol mono-*p*-hydroxybenzoate, trimethylene glycol mono-*p*-hydroxybenzoate, benzyl benzoate, benzyl salicylate, and phenyl benzoate. None of the saturated aqueous solutions of the esters showed any detrimental effect on the growth of the test organisms within a fifteen minute period. With the saturated 30 per cent alcoholic solutions of the esters, an absence of growth was shown in 15 minutes only with the solution of benzyl benzoate, *E. typhi* being the test organism.

The results of the effect of the different glycols on the growth of *E. coli* and *A. aerogenes* in lactose broth are shown in Table 3. The effects of saturated solutions of the esters in lactose broth on the growth of *E. coli* and *A. aerogenes* at pH values of 5.8, 7.0, and 8.9 are shown in Tables 4 and 5. The effects of the esters on the growth of *Saccharomyces cerevisiae* in dextrose broth are recorded in Table 6.

DISCUSSION

Of the four glycols studied, only propylene glycol exhibited any germicidal activity towards *S. aureus,* but ethylene glycol, diethylene glycol, and propylene glycol exhibited a slight activity against *E. typhi* (Table 1).

Of the benzoic acids tested *o*- and *m*-hydroxybenzoic acids were the only compounds which showed germicidal properties with *S. aureus* as the test organism. With *E. typhi* as the test organism, germicidal properties were shown by benzoic, *o*-hydroxybenzoic, *m*-hydroxybenzoic, and *o*-chlorobenzoic acids (Table 2). These results confirm the findings as reported by Wyss and Poe *(19)*.

The concentrations of the glycols required to inhibit gas production in most instances with *E. coli* and *A. aerogenes* were rather large. With ethylene glycol, trimethylene glycol, and propylene glycol, the concentrations required to inhibit the growth and gas production of the organism were between 1:5 and 1:10. Diethylene glycol showed somewhat greater antiseptic powers than the other three glycols, requiring a dilution of 1:25 to inhibit the growth of *E. coli* and a dilution of 1:10 to inhibit *A. aerogenes.*

In media adjusted to a pH value of 7, it was found that the *o*-chlorobenzoates of the glycols exhibited the greatest inhibition of gas production, but the magnitude of the inhibition produced was not found to be significant. The methyl, ethyl, propyl, and butyl esters of the benzoic acids were found to be better inhibitors than the glycol esters. The propyl and butyl esters of *p*-hydroxybenzoic acid exhibited some inhibition. The butyl *p*-hydroxybenzoate showed no gas production with the *Aerobacter* cultures and much retarded gas production with the *Escherichia* cultures. The benzoates and salicylates of methyl and ethyl alcohols were found to be very good inhibitors. *o*-Methoxybenzoic acid completely inhibited growth and gas production for 48 hours with the *E. coli* at pH values of 7.0 and 8.9. With *A. acrogenes* there was no gas production in the medium having a pH value of 8.9.

TABLE 3

TABLE 3

The Inhibition Produced By Different Dilutions of the Glycols in Lactose Broth

	Time	Organism: *Escherichia coli*									
		1:2	1:5	1:10	1:25	1:50	1:100	1:250	1:500	1:1000	1:2500
Ethylene glycol	12 hours	—	—	—	+	3	3	3	3	5	5
	24 hours	—	—	10**	15	15	10	40	35	30	35
	48 hours	—	—	15	20	25	20	45	40	45	40
	72 hours	—	15	20	20	25	20	45	40	40	40
Trimethylene glycol	12 hours	—	—	—	—	+	3	5	5	3	5
	24 hours	—	—	—	35	15	40	35	40	25	25
	48 hours	—	—	10	40	25	45	40	45	35	35
	72 hours	—	—	15	45	30	45	30	45	40	40
Propylene glycol	12 hours	—	—	—	—	+	5	3	5	5	5
	24 hours	—	—	10	40	35	35	15	25	35	35
	48 hours	—	—	15	45	30	35	25	25	35	45
	72 hours	—	—	25	40	45	40	30	25	40	35
Diethylene glycol	12 hours	—	—	—	—	—	+	3	5	5	5
	24 hours	—	—	—	—	—	25	25	30	35	30
	48 hours	—	—	—	—	25	30	35	40	40	45
	72 hours	—	—	—	—	30	35	40	45	35	45
	12 hours		24 hours		48 hours		72 hours				
Lactose	5		40		45		45				

	Time	Organism: *Aerobacter aerogenes*									
		1:2	1:5	1:10	1:25	1:50	1:100	1:250	1:500	1:1000	1:2500
Ethylene glycol	12 hours	—	—	—	—	—	5	5	5	5	5
	24 hours	—	—	—	—	—	5	5	10	15	20
	48 hours	—	—	—	15	15	15	20	15	25	35
	72 hours	—	—	5	20	25	20	20	25	30	35
Trimethylene glycol	12 hours	—	—	—	—	—	5	5	5	5	5
	24 hours	—	—	—	—	—	10	20	15	20	25
	48 hours	—	—	—	10	5	20	25	30	35	25
	72 hours	—	—	—	10	10	20	30	30	35	25
Propylene glycol	12 hours	—	—	—	—	—	5	5	5	5	5
	24 hours	—	—	5	10	15	10	15	10	15	10
	48 hours	—	—	5	20	15	15	20	15	35	30
	72 hours	—	—	5	25	35	25	35	30	35	35
Diethylene	12 hours	—	—	—	—	—	—	5	5	5	5
	24 hours	—	—	—	—	—	5	10	20	10	10
	48 hours	—	—	—	10	35	20	20	30	25	15
	72 hours	—	—	—	20	35	35	30	35	30	25
	12 hours		24 hours		48 hours		72 hours				
Lactose	5		10		25		30				

+ indicates growth but no gas production. ** Percentage gas produced.

TABLE 4

Gas Production in Lactose Broth Saturated With the Derivatives of the Benzoic Acids at Different pH Values
Organism: Escherichia coli

Compound	pH 5.8				pH 7.0				pH 8.9			
	Time in hours				Time in hours				Time in hours			
	12	24	48	72	12	24	48	72	12	24	48	72
Ethylene glycol dibenzoate	5*	35	50	50	5	40	55	55	5	50	70	70
Ethylene glycol disalicylate	5	40	50	50	5	50	45	50	5	80	80	80
Ethylene glycol di-*o*-chlorobenzoate	–	+**	20	25	5	15	40	45	5	10	50	60
Ethylene glycol di-*m*-chlorobenzoate	5	50	60	60	5	50	55	55	5	80	80	80
Ethylene glycol di-*p*-chlorobenzoate	5	30	50	50	5	45	45	50	5	20	70	70
Trimethylene glycol dibenzoate	5	40	50	50	5	35	45	45	5	80	80	80
Trimethylene glycol disalicylate	5	40	50	50	5	40	55	55	5	70	80	80
Trimethylene glycol di-*o*-chlorobenzoate	+	15	15	30	5	20	45	45	+	10	30	40
Trimethylene glycol di-*m*-chlorobenzoate	5	25	50	60	5	40	45	50	5	70	70	70
Trimethylene glycol di-*p*-chlorobenzoate	5	50	50	50	5	50	50	55	5	80	80	80
Propylene glycol dibenzoate	+	10	20	25	5	20	25	25	5	20	30	30
Propylene glycol disalicylate	+	+	20	20	–	5	20	20	+	15	40	50
Propylene glycol di-*o*-chlorobenzoate	+	10	20	25	–	10	25	30	+	15	25	30
Propylene glycol di-*m*-chlorobenzoate	+	+	20	20	–	10	20	30	+	+	25	25
Propylene glycol di-*p*-chlorobenzoate	5	25	40	40	5	15	25	30	5	50	60	80
Diethylene glycol dibenzoate	–	+	30	30	5	10	40	40	–	+	25	40
Diethylene glycol disalicylate	5	40	50	50	5	45	50	50	5	80	80	80
Diethylene glycol di-*o*-chlorobenzoate	–	10	20	30	5	15	35	40	+	+	40	50
Diethylene glycol di-*m*-chlorobenzoate	–	10	15	20	5	10	25	45	5	40	60	60
Diethylene glycol di-*p*-chlorobenzoate	5	30	40	50	5	40	55	55	5	20	40	45
Methyl benzoate	–	+	10	15	–	+	5	15	+	10	25	25
Methyl salicylate	–	+	10	15	–	+	5	10	–	+	10	25
Methyl-*m*-hydroxybenzoate	–	+	10	20	–	+	5	15	+	30	70	70
Methyl *p*-hydroxybenzoate	–	+	25	30	+	15	20	20	+	10	25	30
Ethyl benzoate	–	+	15	20	+	5	10	15	5	15	25	35
Ethyl salicylate	–	+	20	25	+	5	15	15	–	+	30	40
Ethyl *m*-hydroxybenzoate	+	15	20	20	–	5	15	25	5	20	40	40
Ethyl *p*-hydroxybenzoate	–	+	10	15	–	5	15	20	+	10	25	25
Propyl benzoate	+	15	15	20	+	10	30	40	+	10	15	15
Propyl salicylate	+	10	20	20	–	+	15	15	5	30	50	70
Propyl *m*-hydroxybenzoate	–	+	10	25	+	+	15	20	5	30	40	40
Propyl *p*-hydroxybenzoate	+	10	20	20	+	+	10	15	+	10	20	20
Butyl benzoate	+	15	15	15	+	20	20	25	5	20	50	80
Butyl salicylate	–	10	20	30	+	5	20	25	+	10	40	40
Butyl *m*-hydroxybenzoate	+	10	30	40	–	+	20	35	+	10	30	40
Butyl *p*-hydroxybenzoate	–	+	10	15	–	+	+	10	–	–	+	10
Ethylene glycol monobenzoate	–	+	10	10	5	20	25	40	+	10	25	25
Ethylene glycol monosalicylate	+	10	20	30	+	+	5	25	–	+	10	30
Ethylene glycol mono *p*-hydroxybenzoate	5	15	40	50	+	10	25	40	–	+	60	60
Trimethylene glycol mono *p*-hydroxybenzoate	5	25	50	50	5	15	15	35	5	60	80	80
o-methoxybenzoic acid	–	+	10	15	–	–	–	+	–	–	–	–
p-methoxybenzoic acid	–	+	15	15	–	10	15	25	–	10	30	35
o-benzoylbenzoic acid	5	25	25	30	–	20	25	35	+	10	50	60
Phenyl benzoate	5	35	40	40	5	45	50	50	5	30	40	40
Benzyl benzoate	+	10	30	40	+	20	30	35	–	–	–	20
Benzyl salicylate	–	+	15	20	–	+	15	25	5	80	80	80
Lactose	5	30	40	40	5	20	45	50	5	30	40	40

* Percentage gas production. ** + indicates growth but no gas production.

	10	15	20	45	50	5	30	40	40			

* Percentage gas production. ** + indicates growth but no gas production.

TABLE 5

Gas Production in Lactose Broth Saturated With the Derivatives of the Benzoic Acids at Different pH Values
Organism: Aerobacter aerogenes

Compound	pH 5.8				pH 7.0				pH 8.9			
	Time in hours				Time in hours				Time in hours			
	12	24	48	72	12	24	48	72	12	24	48	72
Ethylene glycol dibenzoate	5*	70	80	80	+**	20	60	70	10	80	80	80
Ethylene glycol disalicylate	5	80	80	80	+	10	50	60	10	80	80	80
Ethylene glycol di-*o*-chlorobenzoate	5	15	25	35	+	5	20	30	+	15	40	60
Ethylene glycol di-*m*-chlorobenzoate	5	80	80	80	+	40	50	60	5	80	80	80
Ethylene glycol di-*p*-chlorobenzoate	5	80	90	90	+	15	45	80	10	80	80	80
Trimethylene glycol dibenzoate	5	60	70	70	+	20	40	60	5	40	70	80
Trimethylene glycol disalicylate	5	70	80	80	+	10	50	80	10	80	80	80
Trimethylene glycol di-*o*-chlorobenzoate	5	10	40	50	+	5	20	35	+	10	40	50
Trimethylene glycol di-*m*-chlorobenzoate	5	60	70	90	+	25	60	70	10	60	70	90
Trimethylene glycol di-*p*-chlorobenzoate	5	80	90	90	+	35	55	65	10	60	80	80
Propylene glycol dibenzoate	—	—	15	25	+	5	25	25	5	30	40	50
Propylene glycol disalicylate	—	—	10	15	—	—	10	10	5	15	30	40
Propylene glycol di-*o*-chlorobenzoate	—	—	10	25	—	—	10	25	5	15	40	40
Propylene glycol di-*m*-chlorobenzoate	—	—	25	25	+	+	15	25	10	20	25	30
Propylene glycol di-*p*-chlorobenzoate	10	80	80	80	+	35	45	65	10	50	60	60
Diethylene glycol dibenzoate	—	—	10	35	+	5	20	20	5	20	50	50
Diethylene glycol disalicylate	5	80	80	80	+	25	35	60	10	80	80	80
Diethylene glycol di-*o*-chlorobenzoate	—	—	20	25	+	+	10	20	+	15	40	40
Diethylene glycol di-*m*-chlorobenzoate	—	—	25	35	+	+	15	35	+	+	25	40
Diethylene glycol di-*p*-chlorobenzoate	10	70	80	80	10	20	60	70	10	60	80	80
Methyl benzoate	—	—	—	15	—	—	—	+	—	—	+	+
Methyl salicylate	—	—	20	25	—	—	10	20	+	20	40	40
Methyl-*m*-hydroxybenzoate	—	—	30	40	—	5	25	25	+	25	50	50
Methyl *p*-hydroxybenzoate	—	15	15	20	—	+	15	20	—	+	10	15
Ethyl benzoate	—	—	10	15	—	—	+	15	—	+	10	35
Ethyl salicylate	—	+	10	15	—	+	5	10	+	10	40	50
Ethyl *m*-hydroxybenzoate	+	15	25	25	—	+	20	30	+	20	30	30
Ethyl *p*-hydroxybenzoate	—	+	15	15	—	5	15	15	—	5	15	15
Propyl benzoate	5	35	40	40	+	20	25	30	5	15	30	30
Propyl salicylate	—	+	15	20	+	+	10	25	5	30	40	50
Propyl *m*-hydroxybenzoate	—	+	20	25	+	+	10	25	—	+	30	35
Propyl *p*-hydroxybenzoate	+	10	10	15	—	+	5	10	—	+	25	25
Butyl benzoate	5	10	15	20	—	10	15	20	5	20	40	50
Butyl salicylate	5	20	35	35	—	10	20	30	5	10	20	40
Butyl *m*-hydroxybenzoate	+	10	25	30	—	15	20	40	—	+	30	50
Butyl *p*-hydroxybenzoate	—	—	—	+	—	—	+	+	—	+	+	+
Ethylene glycol monobenzoate	5	20	25	30	+	10	25	25	—	+	25	25
Ethylene glycol monosalicylate	—	10	25	25	+	5	20	20	—	+	+	20
Ethylene glycol mono *p*-hydroxybenzoate	10	25	60	60	+	20	35	60	+	10	60	60
Trimethylene glycol mono *p*-hydroxybenzoate	10	60	80	80	+	25	45	70	10	70	80	80
o-methoxybenzoic acid	—	—	15	15	+	5	20	20	—	—	+	+
p-methoxybenzoic acid	+	20	40	80	+	5	15	25	+	25	30	30
o-benzoylbenzoic acid	—	—	15	40	+	10	20	35	—	+	70	80
Phenyl benzoate	10	60	60	60	+	10	40	60	5	20	40	60
Benzyl benzoate	+	20	40	40	—	5	15	15	—	—	10	10
Benzyl salicylate	—	—	—	—	—	—	+	10	15	70	80	80
Lactose	10	30	50	50	+	15	30	55	5	50	70	70

* Percentage gas production. ** + indicates growth but no gas production.

TABLE 6

Gas Production in Dextrose Broth Saturated With the Derivatives of the Benzoic Acids
Organism: Saccharomyces cerevisiae

Compound	Time in hours			
	12	24	48	72
Ethylene glycol dibenzoate	+*	60**	70	80
Ethylene glycol disalicylate	—	+	90	90
Ethylene glycol di-*o*-chlorobenzoate	—	+	90	90
Ethylene glycol di-*m*-chlorobenzoate	+	90	90	90
Ethylene glycol di-*p*-chlorobenzoate	+	90	90	90
Trimethylene glycol dibenzoate	+	90	90	90
Trimethylene glycol disalicylate	+	10	60	60
Trimethylene glycol di-*o*-chlorobenzoate	—	+	90	90
Trimethylene glycol di-*m*-chlorobenzoate	+	50	90	90
Trimethylene glycol di-*p*-chlorobenzoate	+	80	90	90
Propylene glycol dibenzoate	—	+	50	90
Propylene glycol disalicylate	—	—	—	—
Propylene glycol di-*o*-chlorobenzoate	—	—	+	+
Propylene glycol di-*m*-chlorobenzoate	—	—	+	+
Propylene glycol di-*p*-chlorobenzoate	—	5	80	90
Diethlyene glycol dibenzoate	—	—	+	30
Diethylene glycol disalicylate	—	+	70	80
Diethylene glycol di-*o*-chlorobenzoate	—	+	90	90
Diethylene glycol di-*m*-chlorobenzoate	—	+	90	90
Diethylene glycol di-*p*-chlorobenzoate	+	10	90	90
Methyl benzoate	—	—	—	—
Methyl salicylate	—	—	+	25
Methyl *m*-hydroxybenzoate	—	+	50	90
Methyl *p*-hydroxybenzoate	—	+	80	90
Ethyl benzoate	—	—	—	—
Ethyl salicylate	—	—	+	90
Ethyl *m*-hydroxybenzoate	—	—	—	—
Ethyl *p*-hydroxybenzoate	—	—	—	—
Propyl benzoate	—	—	—	—
Propyl salicylate	—	—	—	—
Propyl *m*-hydroxybenzoate	—	—	+	+
Propyl *p*-hydroxybenzoate	—	—	—	—
Butyl benzoate	—	—	+	25
Butyl salicylate	—	—	15	20
Butyl *m*-hydroxybenzoate	—	—	—	—
Butyl *p*-hydroxybenzoate	—	—	—	—
Ethylene glycol monobenzoate	—	—	—	—
Ethylene glycol monosalicylate	—	—	+	+
Ethylene glycol mono *p*-hydroxybenzoate	—	+	90	90
Trimethylene glycol mono *p*-hydroxybenzoate	—	+	90	90
o-methoxybenzoic acid	+	+	30	90
p-methoxybenzoic acid	—	—	—	—
o-benzoylbenzoic acid	+	60	80	90
Benzyl benzoate	+	+	90	90
Benzyl salicylate	—	—	—	—
Phenyl benzoate	+	+	90	90
Dextrose	+	20	90	90

* + indicates growth but no gas production. ** Percentage gas produced.

The inhibitions produced at pH of 5.8 were approximately of the same order as those produced at neutrality in the media made from most of the esters. Several of the compounds, however, showed more gas production at this pH than at neutrality.

At pH values of 8.9 the propylene glycol esters slowed down gas production to the greatest extent among the glycol esters, but the *o*-chlorobenzoic acid esters of all the glycols showed some inhibitory power. The esters of methyl, ethyl, propyl, and butyl alcohols proved to be less efficient at this pH value than in the neutral or acid media. Also, with the esters of the glycols, the amount of gas produced in 72 hours was very large in comparison to that produced in media adjusted to a pH value of 7.

The effect of many of the esters on growth and gas production was more marked with *Saccharomyces cerevisiae* than with *E. coli* or *A. aerogenes*. The propylene glycol derivatives showed delayed or negative production of gas. Many of the esters of the benzoic acids with the first four mono-atomic alcohols showed negative gas production in 72 hours.

The following compounds completely inhibited growth and gas production with the yeast culture during 72 hours: propylene glycol disalicylate, methyl benzoate, ethyl benzoate, ethyl *m*-hydroxybenzoate, ethyl *p*-hydroxybenzoate, propyl benzoate, propyl salicylate, propyl *p*-hydroxybenzoate, butyl *m*-hydroxybenzoate, butyl *p*-hydroxybenzoate, ethylene glycol monobenzoate, *p*-methoxybenzoic acid, and benzyl salicylate.

GENERAL CONCLUSIONS

1. The phenol coefficients of several glycols and benzoic acids have been determined.

2. Saturated aqueous and saturated 30 per cent alcoholic solutions of 51 esters tested showed little or no detrimental effect on the growth of *S. aureus* and *E. typhi*.

3. The effects of the glycols and various esters on members of the *Aerobacter* and *Escherichia* genera were determined in media of different pH values.

4. The inhibition of fermentation by *S. cerevisiae* was studied in media containing various esters.

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AIR FLOW THROUGH BEDS OF DEHYDRATED VEGETABLES

O. H. SPAUGH

*Western Regional Research Laboratory**, *Albany, Calif.*

In the design of finishing bins for the final drying of dehydrated vegetables, it is necessary to know the resistance offered by these products to the through circulation of air. This article presents equations and experimental coefficients by means of which this resistance may be calculated with a reasonable degree of accuracy.

During World War II the vegetable dehydration industry made increasing use of a separate "bin finishing" step in order to reduce the product to the uniformly low final moisture content required to assure good keeping quality. The bins used for this step remove residual moisture by means of a current of warm, dry air forced through a deep bed of the product. As one phase of a study of finishing bin design, this investigation was undertaken to determine the resistance offered to the flow of air through relatively deep beds of several dehydrated vegetable products. The results have been correlated by means of an empirical equation, so that this resistance (pressure drop) may be calculated with reasonable accuracy when such related factors as nature of product, air flow rate, bed depth, bin size, and air properties are known.

EQUIPMENT

A wooden bin of 10 x 10 inch cross-section and 3 feet effective depth, with a plenum chamber under a screen bottom (Fig. 1) was designed and constructed. A centrifugal fan was used to force air through the bin at a controlled and measured

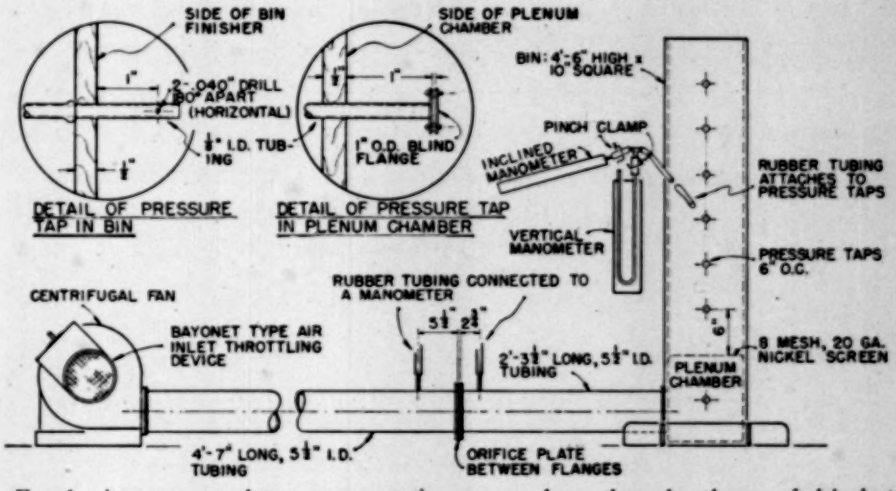
SIDE OF BIN FINISHER
SIDE OF PLENUM CHAMBER
BIN: 4'-6" HIGH x 10" SQUARE
2-.040" DRILL 180° APART (HORIZONTAL)
1" I.D. TUBING
1" O.D. BLIND FLANGE
PINCH CLAMP
INCLINED MANOMETER
RUBBER TUBING ATTACHES TO PRESSURE TAPS
DETAIL OF PRESSURE TAP IN BIN
DETAIL OF PRESSURE TAP IN PLENUM CHAMBER
VERTICAL MANOMETER
PRESSURE TAPS 6" O.C.
CENTRIFUGAL FAN
RUBBER TUBING CONNECTED TO A MANOMETER
BAYONET TYPE AIR INLET THROTTLING DEVICE
8 MESH, 20 GA. NICKEL SCREEN
2'-3½" LONG, 5½" I.D. TUBING
PLENUM CHAMBER
4'-7" LONG, 5½" I.D. TUBING
ORIFICE PLATE BETWEEN FLANGES

FIG. 1. Apparatus used to measure static pressure drops through columns of dehydrated vegetables.

rate. The means used to measure air flow and determine pressure differences are sketched in Fig. 1. A piece of 6-inch diameter stovepipe 3 feet long was used in studying "wall effect," i.e., the effect of different amounts of vertical surface, per unit of bin cross-sectional area, on resistance to air flow.

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* Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

PROCEDURE

Runs were made in the above-described apparatus, using air flow rates ranging from 35 to 170 cu. ft./min. per sq. ft. of bin cross-sectional area.

A number of runs were made to determine the "packing effect," or effect of vertical position in a bed on the static pressure drop per unit of bed depth. Further runs were then made to determine the precise way in which the static pressure drop, through beds of different dehydrated vegetable products, varied with the air flow rate and effective bin size. It was possible to study two effective bin sizes in the same bin by adding "extra vertical surface" in the form of the 3-foot length of 6-inch-diameter stovepipe placed in the center of the bin. For these runs, a 3-foot bed depth was used. Preliminary trials showed that the pressure drop through the screen bottom was negligible compared with that through the 3-foot bed. The static pressure drop per foot of bed depth was, therefore, taken as the static pressure in the plenum chamber divided by the bed depth in feet. During all of these runs the products were rather tightly packed; i.e., the blower was allowed to run during, and for a while after, filling until settling had practically ceased before readings were taken. During each run the atmospheric pressure and wet and dry bulb temperatures were recorded for use in determining the air properties.

The dehydrated vegetable products used in this work were of standard commercial quality, meeting U. S. Army specifications.

CORRELATION OF DATA

The data obtained did not show any significant correlation between the vertical position in a bed and the static pressure drop per unit of bed depth (Fig. 2). This was taken to indicate that the "packing effect" could be considered negligible for this range of bed depths (up to 3 feet). The possibility remains that the effect may be significant for much greater depths.

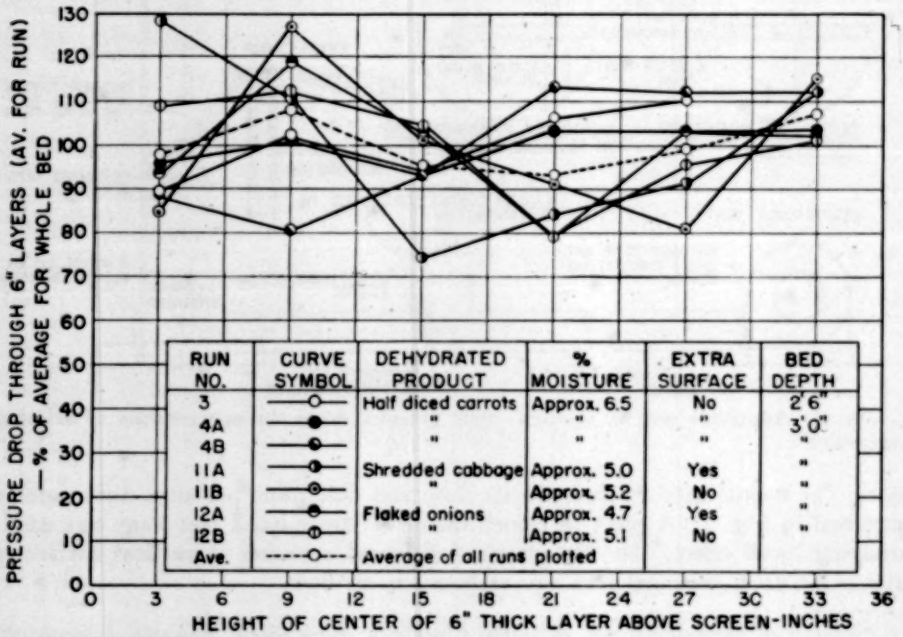
PRESSURE DROP THROUGH 6" LAYERS (AV. FOR RUN) — % OF AVERAGE FOR WHOLE BED
HEIGHT OF CENTER OF 6" THICK LAYER ABOVE SCREEN-INCHES
RUN NO. | CURVE SYMBOL | DEHYDRATED PRODUCT | % MOISTURE | EXTRA SURFACE | BED DEPTH
3 | Half diced carrots | Approx. 6.5 | No | 2'6"
4A | " | " | " | 3'0"
4B | " | " | " | "
11A | Shredded cabbage | Approx. 5.0 | Yes | "
11B | " | Approx. 5.2 | No | "
12A | Flaked onions | Approx. 4.7 | Yes | "
12B | " | Approx. 5.1 | No | "
Ave. | Average of all runs plotted

FIG. 2. Packing effect—average air flow resistance vs. height in column.

When plotted, the data on air flow resistance (pressure drop vs. air flow rate) for the various products followed smooth curves without any large degree of scattering (Fig. 3). When the same data were plotted on log-log paper, it was found that the curves were approximately straight lines, indicating an equation of the form,

$$P = U^n \qquad (1)$$

where P = static pressure drop through product in the bin, expressed in inches of water per foot of bed depth, and U = the average "apparent" velocity of the air, expressed in cu. ft./min. of air flow per sq. ft. of bin cross-sectional area.

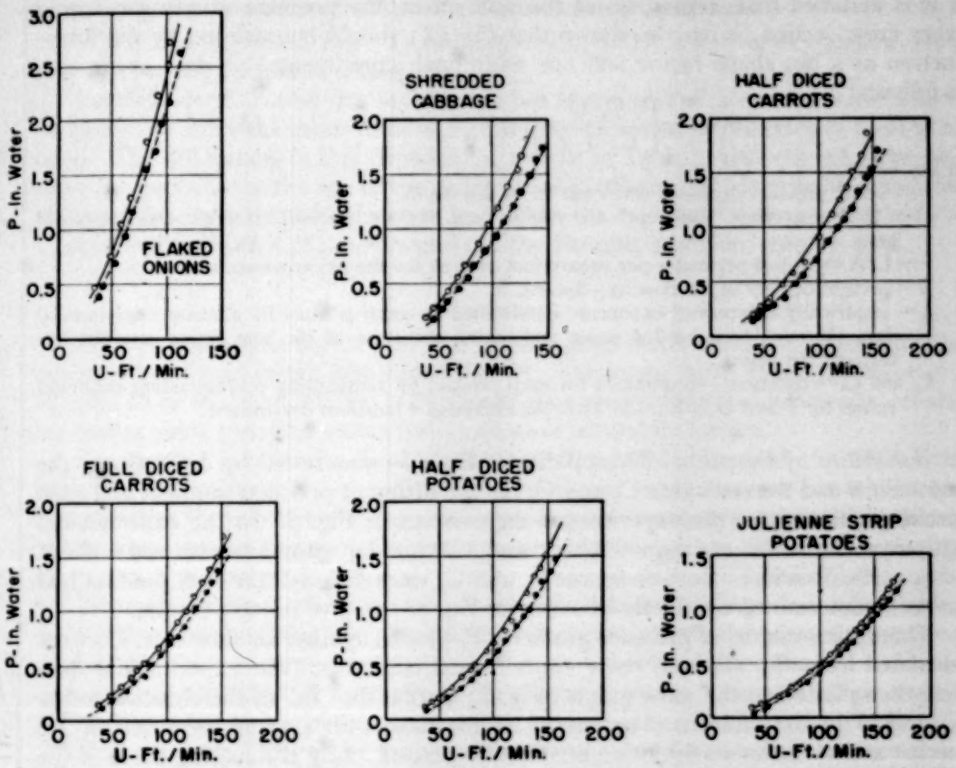

FIG 3. Pressure drop vs. air flow rate—for the flow of unheated air through 10" x 10" x 3' columns of dehydrated vegetables. The individual points represent the experimental data, and the curves represent equation (3). The dotted curves and solid points indicate "with extra surface" conditions (r = 9.32), and the solid curves and open points indicate "without extra surface" conditions (r = 4.80).

Effect of Air Density. In the turbulent flow of gases, where pressure drop is small compared with the absolute pressure, the pressure drop is approximately proportional to the weight density of the gas flowing *(2)*. Eq. (1) may, therefore, be modified to

$$P = C\,w\,U^n \qquad (2)$$

where w = weight density of the air flowing, lb./cu. ft. The equation will then take into account any differences in air density.

Effect of Air Viscosity. For turbulent flow of gases through granular solids, Chilton and Colburn *(1)* found that the pressure drop varied approximately as the 0.15 power of the viscosity of the gas. In this investigation the air viscosity was

about 0.018 centipoise and at maximum bin drying temperatures of around 200° F. (93° C.), the viscosity would be about 0.022 centipoise. The increase in pressure drop, caused by this maximum expected increase in viscosity, would be around 3 percent, which is well within the experimental error. To avoid unnecessary complication of the equation, this effect was considered negligible.

Wall Effect. The data (Fig. 3) show that with increase in amount of vertical surface, per unit of cross-sectional area, resistance to air flow is decreased. During these runs, a layer of high-velocity air was found to exist near the vertical surfaces in the bin. The desired empirical equation should take this "wall effect" into account. If it is assumed that, regardless of the wall effect, the pressure is uniform across every cross-section, it may be shown that Eq. (2) should be modified by the introduction of a bin shape factor and one additional experimental product coefficient, as follows:

$$P = w\left[\frac{C_1 U}{C_2 + r}\right]^n \qquad (3)$$

In Eq. (3),

P = static pressure drop—in water per ft. of bed depth.

$U = Q/A$ = average "apparent" air velocity—cu. ft./min. per sq. ft. of bin cross-sectional area.

$r = L/A$ = feet of perimeter per square foot of area for the bin cross-section.

w = weight density of air flowing—lbs./cu. ft.

n = empirically determined exponent—determined for each product by plotting experimental data (P vs. U) on log-log paper and taking the slope of the best fitting straight line through the points.

C_1 and C_2 = constants—determined for each product by substituting corresponding empirical values for P and U in Eq. (3) after the exponent n has been determined.

Reliability of Equation. The validity of Eq. (3) was tested by determining the exponent n and the constants C_1 and C_2 for the different products studied, and then checking points from the experimental data shown in Fig. 3. In the experimental equipment the values of r were 9.32 ft.$^{-1}$ and 4.80 ft.$^{-1}$ for operation with and without extra vertical surface. Both constants C_1 and C_2 were different for each product and had to be determined accurately in order for Eq. (3) to give reliable results.

Theoretical curves of pressure gradient, P, plotted against air flow rate, U, were calculated from Eq. (3) and these experimental constants. The experimental data were then plotted on the same graph (Fig. 3) so that the "fit" of the equation to the data could be determined. The curves fit the data with a mean deviation of 2.8 percent and a maximum deviation of about 20 percent. (By eliminating three of the 214 experimental points determined, the maximum deviation reduces to about 9 percent.)

Values determined during this investigation for the exponent n and the constants C_1 and C_2 are given in Table 1.

TABLE 1

Mean Values of Constants in Equations (3) and (2)

Product	Dimensions before Dehydration	Moisture	n	C_1	C_2	C*
		%				
Julienne strip potatoes	¼" x ¼" x random	8.0	1.82	2.68	91.1	0.00163
Half-diced potatoes	⅜" x ⅜" x 3/16"	7.5	1.79	1.72	41.8	0.00332
Full-diced carrots	⅜" x ⅜" x ⅜"	7.1	1.71	2.41	55.2	0.00472
Half-diced carrots	⅜" x ⅜" x 3/16"	6.6	1.69	1.72	33.4	0.00665
Shredded cabbage	3/16" x random	5.9	1.75	1.76	32.7	0.00602
Flaked onions	⅛" x random	4.9	1.60	3.90	38.1	0.02615

* The values of C given here for use in Eq. (2) apply only for larger bins where r is equal to or less than 1.0.

SIMPLIFIED EQUATION

The wall effect is substantial in a bin of such small cross-section as was used in these experiments. The bin shape factor, r, ranging from 4.8 to 9.3, was not negligible in comparison with the constant C_2 to which it is to be added in Eq. (3). In bins of commercial size, however, the wall effect would become negligible. For example, the smallest bin that is likely to have any practical interest—3 feet square—has a shape factor of only 1.3 ft.$^{-1}$, and for most commercial bins the factor would be less than 1.0 ft.$^{-1}$. Since C_2 ranges from 30 to above 90, little error will follow if r is dropped from Eq. (3). The equation serves its purpose as a means for correlating the data secured in the small experimental equipment.

When r is neglected, Eq. (3) reduces to Eq. (2). The overall constant, C, is given as the last column in Table 1.

Further simplification can be effected, but at the cost of a much greater loss of precision, by using the mean value of 1.75 for the exponent of the velocity term in all cases. The differences in this exponent, n, shown in Table 1, are believed to be real, since the probable errors are of the order of only 0.01 to 0.03. It may be noted that all six of the experimental values are lower than the exponent of the velocity term in Chilton and Colburn's *(1)* modification of the Fanning equation, namely, 1.85.

DISCUSSION

Eq. (3) represents the data of this investigation better than any other equation developed or found in the literature (Fig. 3). For larger bins, where the value of r is equal to or less than 1.0, Eq. (2) should give results that are sufficiently reliable for design work, provided values for C and n are accurately known.

Commercial practice in the United States has tended toward the use of the finishing bin primarily as an equalizing device—that is, as a means for eliminating irregularities in moisture content of the product as it comes from the dehydrator. While some further drying is desired, a reduction of more than 2 to 3 percent in the mean moisture content is unusual. Under these conditions dehydrated vegetables are substantially rigid solids, and no perceptible further shrinkage in volume occurs during the additional drying. The moisture content of the dehydrated vegetables used in these experiments was determined both before and after the air resistance runs; values tabulated in Table 1 are the means of the two determinations, which differed by a few tenths of one percent, due to partial equilibration with the flowing air during the run. The mean values are within the range that would be normal for the usual type of bin operation.

No significant correlation was found between vertical position in a 3-foot bed and the static pressure drop per unit of bed depth. It is unlikely that dehydrated vegetables of low moisture content would undergo a significant degree of packing due to the superimposed load even if the bed depth were doubled.

If a bin were to be designed to accomplish a substantial degree of drying, say from 15 to 20 percent moisture to 4 or 5 percent, the constants determined in these experiments should be used with caution. Under those conditions the volume shrinkage would not be negligible, and the load would tend to settle and pack. Resistance to air flow would increase as drying progressed. The bed depth would undoubtedly also have to be limited, to avoid packing of the bottom layers of the somewhat-pliable material under load.

The dehydrated vegetable products used in this investigation were taken from 5-gallon cans which had been subjected to considerable handling. It is not unlikely, therefore, that these products contained a considerably greater proportion of "fines" and a somewhat smaller average particle size than similar products taken directly

from trays. For products subject to crumbling, therefore, the values for C and n given in Table 1 are likely to be somewhat conservative; i.e., they may indicate higher air-flow resistances than will actually be offered by similar products taken directly from the trays. The values given for flaked onions are probably too conservative to correspond with usual plant practice, since the product had been passed through mechanical breaker rolls to reduce the pieces to uniform size before being packaged.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to W. B. Van Arsdel for his advice and guidance and to E. Lowe, who carried out preliminary work on this problem and offered helpful suggestions. The author is also indebted to Margaret Losee for her assistance in the preparation of curves and drawings.

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METHODS USED BY THE DAIRY INDUSTRY TO IMPROVE SANITARY CONTROL THROUGH EQUIPMENT DESIGN* DAIRY PRODUCTS AND LIQUID FOODS

E. H. PARFITT
Sanitary Standards Subcommitte of The Dairy Industry Committee
Chicago, Illinois

REVIEW PAPER

This paper is an outline of the procedure used by the dairy industry to standardize design of dairy equipment from the standpoint of making parts uniform and interchangeable, and from the standpoint of increasing ease with which the equipment may be cleaned, kept in a sanitary condition, and inspected.

I. THE DEVELOPMENT OF THE DAIRY INDUSTRY'S INTEREST IN EQUIPMENT DESIGN

The interest of the dairy industry in equipment design for the purpose of improving the quality or sanitary control of its products was probably instigated when laboratory methods were introduced for measuring quality of milk. The introduction of the bacterial count and the sediment test as a means of judging quality caused users of dairy equipment to seek ways and means to improve sanitary control through equipment design.

Prior to 1923 the dairy industry in general recognized the necessity of the dairy equipment used being designed with consideration to ease of cleaning. Laboratory tests demonstrated that to maintain clean surfaces contacting milk, and to minimize bacterial recontamination, it was necessary after each usage to disassemble pipelines, pumps, and like equipment for cleaning.

The necessity of daily disassembling equipment for cleaning, and the necessity of minimizing possible recontamination to milk after pasteurization caused dairy sanitarians to become interested in equipment design. Their approach to the problem of design was not uniform, as would be expected, with the result that there arose conflicting points of view as to what constituted satisfactory sanitary design of dairy equipment. In some cases equipment design was not based on public health reasoning. An example of difference of opinion as to what constitutes sanitary design is illustrated by standards for milk storage tanks in the variation of inside diameters, (84 inches, 96 inches, and 110 inches), the size of milk outlet valves on milk storage tanks, (2 inches or 3 inches), and the method of attachment of the valve to the tank. Other examples could be cited.

Due to lack of establishing industry-wide sanitary standards, criticism of design on the part of sanitarians was usually not made at the design stage, but after the equipment was installed in the milk plant. The dairy industry itself was somewhat to blame for lack of standards, for as an industry there was no insistence on making specific design details that would enable the manufacturers of dairy equipment to know how the machine should be built to meet the sanitary requirements and to allow the purchasers to know how the change in design would assist in improving the sanitary control of the products handled.

In 1923, the first national effort to improve sanitary control through equipment design was made by the introduction of the U. S. Public Health Service Ordinance and Code. One of the purposes of this Ordinance and Code was to increase the safety of milk by preventing its recontamination after pasteurization. To do this, the ordinance outlined some fundamental principles of equipment design. It stated

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that surfaces which contact milk are to be smooth, impervious, and not readily corrodible.

Later editions of the Ordinance and Code described design of specific pieces of equipment such as theremometers, milk valves, and pipe connections. The Ordinance made general reference to the design of vat covers and covers for surface coolers for the purpose of minimum post-pasteurization contamination. Interest in equipment design increased as the U. S. Public Health Service Ordinance and Code increased in popularity. The work of the U. S. Public Health Service was the first attempt on a national scale to improve sanitary control through equipment design.

As milk quality became more uniform (as determined by platform tests and sanitary conditions on farms) the importance of the character of equipment design became more apparent. In some areas, whether or not milk or a milk product could be sold was in part based upon the character of design of equipment used in the plants in which the products were manufactured. This emphasis on equipment design caused the development of a keen interest on the part of equipment manufacturers. Consequently, in order to assure acceptance by the buyer, they sought approval for equipment they fabricated. The lack of uniformity as to what constituted the sanitary design of dairy equipment was costly to the dairy industry. Not only did it cause increased cost in fabrication, but it resulted in the user's doing the testing of equipment for practicability and the value of the design in improving quality and reducing recontamination. This period of development, while costly, did much to establish basic principles of sanitary design in the minds of those interested in design.

The interest in equipment design was confined, for the most part, to that equipment used in the pasteurization of milk and milk products, and the public health reasoning behind this interest was to minimize possible recontamination after the pasteurizing process. This interest expanded to other products, for the past war caused many milk and milk product plants to become more diversified, resulting in expansion of their markets. In some instances plants whose equipment met sanitary requirements of a given local area found that their equipment did not meet the sanitary requirements of other areas, due to differences of interpretation as to what constituted satisfactory sanitary design. The need for a clear definition of what constituted satisfactory design was clearly brought into focus when purchasers of new equipment desired to be assured by fabricators that the new equipment was of acceptable design to any of the number of areas into which they might desire to ship milk or milk products.

In addition, the new equipment, because it was fabricated for the most part from stainless steel, had longer life, lower depreciation value, and purchasers desired to be assured that new stainless steel equipment was designed so that it would be acceptable over a longer period of time than the equipment which had been fabricated from tin-copper.

Prior to the war this interest in sanitary control through equipment design had been principally confined to the bottled milk industry. Through committees in the International Association of Milk Dealers and the Dairy Industries Supply Association much had been done to crystallize the thinking as to what constituted sanitary design in equipment.

In 1939 the evaporated milk industry formed a committee with the purpose of securing uniform sanitary control through equipment design by formulating minimum design standards for much of the equipment used by that industry. The formulation of these minimum standards in the bottled milk and evaporated milk industries was done with the hope of assuring buyers of equipment in these industries

that equipment purchased on the basis of these standards conformed to the best thinking and experience of those interested in equipment design, and that the equipment could not be criticized for failure to conform to accepted details of sanitary design.

II. ORGANIZATION OF THE DAIRY INDUSTRY TO IMPROVE SANITARY CONTROL

a. *The initial development of sanitary standards for equipment:* The necessity for disassembling and cleaning pipelines for handling milk resulted in the use of a large number of different types of fittings. In many instances these fittings were not interchangeable so, while simplifying the process of disassembling and cleaning, the process of assembly became more complicated.

Because of the difficulties with pipeline fittings, a committee was formed in the International Association of Milk Dealers for the purpose of securing interchangeability of fittings. That this committee might have the advantage of the viewpoint of the sanitarians, a similar committee was formed in the International Association of Milk Sanitarians and a cooperating committee was also formed by the Dairy Industries Supply Association, representing the manufacturers of fittings. The committees of these three associations had as objectives: (1) to develop fittings which were sanitary in design, and (2) to so standardize the fittings that equipment purchased from different fabricators would be interchangeable. The findings of these committees were published in May, 1939, February, 1940, and May, 1940, in a magazine published by the Dairy Industries Supply Association, known as *The Association Quarterly*. In addition, a report was made on the fittings by the Committee on Sanitary Procedure of the International Association of Milk Sanitarians. The fittings so approved by the three associations were known as meeting the 3A Standard.

b. *Need of an over-all industry coordinated program:* The sanitary standards programs of the International Association of Milk Dealers and the Evaporated Milk Association indicated the value of having sanitary standards of design for dairy equipment. The dairy industry had advanced to a point where it was no longer sufficient that the lining of a vat or tank be made of stainless steel, but the equipment had to drain freely within narrow tolerances, had to be constructed so that it could be easily cleaned, and all surfaces had to be free of cracks and indentations. Workmanship on dairy equipment had improved so that well defined standards could be readily attained. At the close of the war the dairy equipment manufacturers manufacturing war equipment had learned many new skills that could be applied to dairy equipment. The conclusion of the war also resulted in users, sanitarians, and equipment manufacturers again taking up the problem of further improvement of equipment design that would result in improved sanitary control of the finished product. The war had also introduced the multiple use plant so that this interest was not confined to the bottled milk and evaporated milk industries. Other industries such as dry milk, butter, cheese, and ice cream desired to be assured that the machines they purchased were of sanitary design and without unnecessary frills.

Through the Dairy Industry Committee, in the Fall of 1944, representatives of all branches of the dairy industry began to crystallize their ideas as to how a coordinated program on sanitary control through equipment design could be inaugurated. They had in mind a program somewhat similar to that which had been developed under the 3A designation. Through group discussion, leaders in the industry reasoned that if each branch of the industry—bottled milk, evaporated milk, butter, cheese, dry milk, ice cream, and the dairy supply manufacturers, would appoint to a committee a representative group of men whose interest was in equipment design,

this group, after studying the problem, could formulate minimum sanitary standards for specific pieces of equipment common to all branches of the dairy industry.

The Dairy Industry Committee wished to be assured that the work of this proposed committee would have the cooperation of the two national sanitarians' organizations. Contacts were made with the International Association of Milk Sanitarians and the U. S. Public Health Service, and cooperation was assured. Late in 1945 the committee, known as the Sanitary Standards Subcommittee of the Dairy Industry Committee, was formed.

c. *Organization of work:* The Sanitary Standards Subcommittee of the Dairy Industry Committee developed the following procedure for its work in sanitary control through equipment design:

(1) Equipment common to the dairy industry is accepted for study on recommendation by regulatory groups or industry.
(2) A task committee of the Sanitary Standards Subcommittee is appointed to initiate tentative standards for study purposes.
(3) The task committee submits its report to the Sanitary Standards Subcommittee.
(4) The Sanitary Standards Subcommittee, on reviewing the report at a group meeting, resubmits its revised report to each industry branch sanitary standards or simplified practice committee. This procedure gives the tentative study report national coverage.
(5) The Sanitary Standards Subcommittee meets again with the task committee and reviews all comments and draws up a report which is again resubmitted to the industry through the industry trade associations.
(6) On arrival of acceptable sanitary standards for equipment, these standards are submitted to the Dairy Industry Committee.
(7) On approval of the Dairy Industry Committee, the tentative sanitary standards are submitted to the Committee on Sanitary Procedure of the International Association of Milk Sanitarians and the Milk and Food Unit of the U. S. Public Health Service who in turn submit them to each of the members of their committee.
(8) A joint meeting is held with the Sanitary Standards Subcommittee of the Dairy Industry Committee, the Committee on Sanitary Procedure of the International Association of Milk Sanitarians, and the Milk and Food Unit of the U. S. Public Health Service, to arrive at standards.

The sanitary standards arrived at by the action of the three agencies are to be published in the *Journal of Milk and Food Technology,* and reprinted in the dairy trade journals. Reprints from the *Journal of Milk and Food Technology* are to be distributed to all buyers of equipment and fabricators of equipment through their respective trade associations. It is felt that by this procedure all in the dairy industry will have knowledge of the standards which have been promulgated.

d. *Work accomplished to date:* The Committee was first organized in January of 1946. To date it has developed sanitary standards for thirty-seven fittings for milk piping, as well as sanitary standards for milk storage tanks, milk pumps, weigh cans and drop tanks for raw milk, and homogenizers.

Some of the specific details that have been standardized are best shown by a review of the standards for milk storage tanks which were published in the May-June, 1946 issue of the *Journal of Milk Technology.* To support the standards formulated, public health reasons are given. Among the important items upon which agreement had been reached are the following:

(1) The establishment of a No. 4 mill finish as being the minimum standard finish for stainless steel that comes in contact with milk.
(2) The defining of location of welds on the inside surface so that they are located to permit the grinding and polishing of the weld on a flat surface.
(3) The establishment of a knuckle radius where the inside head joins the lining of the tank to be not less than ¾-inch.
(4) The location and type of outlet valve mounting.
(5) Location of air vent, gauge openings, sight and light glass.

(6) The type and efficiency of agitators.
(7) The maximum slant necessary for complete drainage of the tank.
(8) The acceptable maximum diameter of a tank. (96 inches, unless provision is made for cleaning tanks of greater diameter.)

Milk pumps: The development of standards for centrifugal and positive rotary type milk pumps has not been an easy task. Before agreement could be secured among the three groups the standards were revised seven times. The standards developed limit the type of material from which pumps shall be fabricated to stainless steel, nickel alloy, or a product as corrosion resistant as nickel alloy.

In the construction of the pump, all surfaces which contact milk are to be readily accessible for cleaning and inspection and are to be easily removable. All exterior surfaces are to be self-draining. The standard defines the method of mounting the pump; it is to be mounted on legs, the lowest part of the base from the floor to be not less than four inches, unless it is the type of pump which must be grouted in, and in that case it shall be mounted on a base for grouting and sealing.

Threads shall not be in contact with the product, but because there are pumps now on the market which the manufacturer feels cannot be manufactured unless threads are provided, these manufacturers have been granted an exception to January 1, 1949. The shaft seal is to be of sanitary type, easily removable for inspection and cleaning.

Homogenizers: The cylinder is to be constructed so that it will be possible to brush through all openings and passages unless the proportions and locations of the openings are such as to permit easy cleaning without brushing through. The ports connecting the valve chambers are to be readily accessible for brush with no dead ends, and the gauge used on the homogenizer is to be of the sanitary diaphragm or pressure bulb type.

Work in progress: Standards are now being developed for milk transportation tanks, milk pails and strainers, milking machines, electric motors, can washers, and heat exchangers. These standards have not as yet reached the stage at which they can be reviewed by the sanitarians' organization or the U. S. Public Health Service.

The Committee has undertaken an aggressive program since its organization on January 3, 1945. Its efforts have brought the attention of the dairy industry to the value of work that can be done on a national level in the field of sanitary control through equipment design. The Committee has had excellent support from the six product branches of the dairy industry and the manufacturers of dairy equipment. In the year and a half of its existence, because of the cooperative support it has received from the sanitarians' organizations, it has been able to accomplish more than many critics of the dairy industry felt could be accomplished in a ten-year period.

The Committee realizes that the standards that are promulgated might be considered by some to place a handicap in the way of further development in dairy equipment. In order that the standardization work done by the Committee will not retard any possible progress in the use of new developments, materials, design, or construction, each standard that is promulgated has a preamble which reads as follows:

> It is the purpose of the IAMS, USPHS, and DIC in connection with the development of the 3A Sanitary Standards program, to allow and encourage full freedom for inventive genius or new developments. Specifications which are developed and which so differ in design, material, construction, or otherwise, so as not to conform with the following standards, but which in the opinion of the manufacturer or fabricator are equivalent or better, may be submitted at any time for the consideration of IAMS, USPHS, and DIC.

The success of the undertaking of this joint effort on the part of the Dairy Industry Committee, International Association of Milk Sanitarians and the U. S. Public Health Service will depend upon:

(1) The degree of support that is given by regulatory groups in seeing that fabricators manufacture equipment that meets the 3A standard.

(2) Regulatory groups making sure that fabricators whose equipment does not meet the 3A sanitary standards is not designated or sold as meeting these standards.

(3) The individual sanitarian's supporting these standards, and demonstrating his willingness to go along with these standards rather than attempting to modify them according to his individual thinking.

(4) Maximum publicity being given to these standards so that buyers of equipment may specify that the equipment be of sanitary design meeting the 3A standards.

(5) Other branches of the food industry, other than the dairy industry, reviewing these sanitary standards for the purpose of incorporating them into their fields so that all branches of the food handling industry can be functioning from a common sanitary standard.

The Sanitary Standards Subcommittee of the Dairy Industry Committee has as its membership the following:

E. H. Parfitt, Chairman

American Butter Institute
Ray Alberts
G. W. Shadwick, Jr.

American Dry Milk Institute
D. S. Flack
J. T. Walsh

Dairy Industries Supply Association
H. S. Fielder
G. W. Putnam

Evaporated Milk Association
E. H. Parfitt

International Association of Ice Cream Manufacturers
O. M. Johnson
R. O. Tardiff
F. E. Uetz

Milk Industry Foundation
T. J. Kullman
R. J. Winning

National Cheese Institute
J. S. Barnes
A. E. Nessler
Z. D. Roundy

The Committee on Sanitary Procedure of the International Association of Milk Sanitarians consists of the following:

C. A. Abele, Chairman
E. B. Buchanan
Paul Corash
C. B. Dalzell
M. R. Fisher
A. W. Fuchs
R. E. Irwin
I. M. Marty
Sol Pincus
G. W. Putnam
W. D. Tiedeman
Harold Wainess
C. W. Weber

The Milk and Food Unit of the U. S. Public Health Service consists of the following:

A. W. Fuchs, Chairman
John Andrews
E. K. Day
A. B. Freeman
R. W. Hart
W. H. Haskell
R. J. Helvig
L. H. Male
M. M. Miller
J. L. Minkin
C. M. Moss
E. R. Price
H. B. Robinson
Harold Wainess

NEW ADVANCES IN SCIENCE*

GEORGE RUSSELL HARRISON
Massachusetts Institute of Technology, Cambridge 39

Mr. Chairman, Members and friends of the Institute of Food Technologists. While I was sitting here, listening to the introduction of people at the head table, two thoughts crossed my mind. I wondered whether the Chairman was going to call on me too as an old timer. It so happens that I talked to this same group in 1939 on "Absorption Spectroscopy," so in that sense, I *am* an old-timer. Also, the frequent reference to the *Institute* made me think of another institute, the American Institute of Physics, of which I am chairman; so this is a fine opportunity for me to bring to the Institute of Food Technologists the greetings of the 9,000 physicists who are members of the American Institute of Physics.

I note, Mr. Chairman, that someone has tampered with the title of my remarks. I was originally told to speak on "New Directions in Science." Now, I find I am to talk on "New Advances in Science." There really is a difference, because the subject of "New Advances in Science" has an element of prophecy in it. I recently learned that it is dangerous to prophesy, particularly when ladies are present.

I was asked to talk on a scientific subject, in the intermission of one of the Sunday afternoon radio broadcasts of a symphony program. I was warned that there would be 8 million women listening in, and I must say something to interest them. My subject was "Custom Built Molecules." I mentioned the fact that in the old days, when a chemist wanted to create something new, he took out a test tube, poured something into it out of one bottle and then out of another bottle and watched them fizz. Then he poured the mixture out into a beaker and looked at it to see if it was worth anything. Nowadays, the chemist doesn't work that way, because he knows how atoms are built. If he knows the properties of an atom, he can design a molecule with it. I took as an example freon, the material used in household refrigerators. I mentioned the fact that a few years ago, when people were trying to build a refrigerator, they found all the vapors available had something wrong with them; either the material was noxious, toxic, or corrosive and ate the insides out of the refrigerator, or had something else the matter with its molecules. So the chemists decided to build some new molecules of their own, in order to build better refrigerators. So they took the molecule nearest to being right, which was carbon tetrachloride, and looked at it to see what was wrong with it. They found it was a little bit too heavy; so they decided they would fit a couple of fluorine atoms into it; thus they made a new molecule, CF_2Cl_2, which they called freon. That, as you know, made the modern household refrigerator the efficient thing that it is. Thus they tailor made a molecule to the customers' specifications and revolutionized an industry.

Well, I would have been all right if I had stopped there, but I kept thinking about the 8 million women and I thought I would talk about textiles. I pointed out the fact that silk had been one of the most valuable textiles for thousands of years, because the silkworm happens to be able to spin out of its nostrils two fine filaments of a plastic material which hardens into strands which may be as much as a third of a mile long. These filaments are made of molecules which hang together in such a way that the thread is very elastic, and will stretch quite a bit without snapping. As every woman knows, silk stockings were for a long time the best kind of stockings. Naturally, this made the chemist jealous, because he felt that a scientist should be

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able to do anything that a silkworm could do. So he decided to develop a material stronger and cheaper than silk, and eventually developed rayon. Rayon stockings turned out to be cheaper, but they weren't quite good enough, because the rayon fibre was not as strong as the silk fibre. But the chemists weren't discouraged, and they worked and worked and finally developed nylon.

These nylon stockings turned out to be both cheaper and better than silk.

Well, if I had stopped there, I would have still been all right, but I didn't. I said: "There is no reason to suppose that chemists are going to be satisfied with the nylon molecule as it is today. There is every reason to believe that chemists are working on new improved molecules, which will give even stronger textile filaments. I have no doubt that eventually we will have super-nylon molecules.

Well, I took the train back to Boston, and went to bed feeling fairly normal. When I woke up next morning, I found on the front page of every Boston paper: "M. I. T. savant (I don't know what a savant is, but I would rather see than be one) predicts stockings to last ten years!"

Well, that was the morning papers. By the time the evening papers came out, ten-year stockings were spread all over the United States. For days my colleagues would come by at the luncheon table and lean over and say: "My wife says to tell you that she wouldn't wear a pair of stockings ten years even if they did last that long!"

I got a letter from Spain asking for the exclusive Spanish rights to the importation of my ten-year stocking. I got a letter from a lady in Hollywood saying, "I am so glad you are helping us large women. I love to wear nylons, but they bag at the knee."

Well, you see why I am not going to do any prophesying this evening, with all these ladies present.

At M. I. T., Food Technology is in the School of Science, not in the Engineering School. I think that food technologists, being a young and up-and-coming group, are probably as aware of the importance of scientific research as any group in the world today.

I suppose you all think of food technology as having to do with the storage and distribution of matter. You probably feel that you are people who make big molecules out of little ones. That is true enough, but to my mind, food technology is, primarily, a matter of distribution of energy. You are a group of scientists and engineers engaged in packing, storing and distributing energy. It is very important to realize the importance of energy. Every cent we spend is for energy and its control; that, for the know-how of making energy do the things we want it to do.

Suppose you buy a basket of strawberries. They represent so much matter. The berries are made of cells, and they in turn of molecules, atoms, electrons, protons, and neutrons. But also they represent energy which we are interested in removing from these indestructible atoms.

Suppose your wife wants to buy a new hat. Are you paying for the matter in that hat? Of course not! You could burn the hat in the fireplace and catch all the smoke and keep the ashes, and you still have all the matter in the hat. If you were a really clever super-physicist, you could take those ashes and the smoke molecules apart until their constituent atoms were all separate, then re-arrange them into new molecules. You would need some enzymes to help you, and finally you would make the molecules into textile fibres and a feather or two, and ultimately you would have a hat. All you would have to do to recreate the hat from smoke and ashes would be to use some energy with sufficient "know-how."

Take Aristotle. When I listened to Dr. Ball talk about the importance of mathematical analysis in determining whether an experiment is correct or not, I thought

of Aristotle. Now, Aristotle didn't know how to make an electric refrigerator. Why didn't he? Because although he had all the iron and all the copper he needed, and all the atoms necessary to make freon molecules, he didn't have the "know-how." Today almost any intelligent person could make a refrigerator.

But Aristotle is the past; let us consider the future. The automobiles that we drive today are inefficient, smelly, and contain a lot of what Vannevar Bush called Christmas tree engineering. By this he meant that process by which one gadget is built on another gadget to make the first work right. For instance, your automobile gets hot, so you have a cooling system. The cooling system freezes in the winter time, so you have to use anti-freeze. The anti-freeze boils out, and then you need a thermostat. There is always a sub-twig on each branch, and if you go through all of the details of the automobile, you have a Christmas tree full of gadgets placed on gadgets to keep other gadgets from failing in their operation.

If we would give up gasoline as a fuel for automobiles and turn to the electric car, all of these troubles would evaporate immediately. Look what you could do! You could have a motor on each wheel. You could throw away the self-starter, the cooling system, the thermostat, the anti-freeze, the clutch, and the transmission, and you could even throw away part of the braking system. To make a long story short, you could get rid of everything but the four wheels and the chassis, and you would end up with a big storage battery and four motors, and when you went down hill, it would return energy. Imagine a modern car pumping gasoline into the tank, going down hill!

Why don't we have electric automobiles? There is just one reason. We can store twenty times as much energy in a pound of gasoline as we can in a pound of storage battery. In other words, in order to be able to load up the car with enough stored energy to carry us 200 miles, we would have to have storage batteries which weighed twenty times as much as a tankful of gasoline does. Why shouldn't we make these storage batteries out of light beryllium instead of heavy lead? The answer is that we don't know how. Thus the automobile problem is a combination of energy and know-how.

All this may seem far-fetched, but it is only an exaggeration of the type of thing that governs our standard of living.

Here are five seconds' worth of statistics. In 1926, in the United States, 200,000 refrigerators were sold at $400 apiece, average. Those were the same refrigerators that Aristotle didn't know how to make. In 1936, 2,000,000 refrigerators, ten times as many, were sold at an average of $185.00 apiece—less than half the previous price.

Take radios: In 1926 1,750,000 radios were sold in the United States, averaging $114.00 apiece. In 1936, ten years later 8,750,000 radios were sold at an average of $54.50 apiece. So you have six times as many radios sold at less than half the price.

You see what this means. First of all, it was made possible by scientific and technological research. And what it means is that everybody is richer. The customers get better radios for less money, ten times as many are sold, the government collects more taxes, and everybody is better off.

Where has this new wealth come from? It's not like taking rabbits out of a hat. You don't take money away from somebody and give it to somebody else; you create it fresh, because of increased know-how of the control of energy, which is at the bottom of all our economic wealth.

Let us take a look around at the different countries in the world today and see the relative wealth levels. Here in the United States, the average citizen has a certain amount of energy at his disposal; this energy is the equivalent of that of eighty men working three shifts a day, full time. The average citizen of England is

not as well off as the average citizen in the United States, having only 40 slaves. In Italy, the number is cut down to 20. In China, they have only one-twentieth as many as we have. We can relate the wealth level of society directly to the availability of energy, the machines to manage this energy and the know-how to operate them.

Naturally nuclear energy comes into this picture, and that will cause a tremendous revolution. I brought along a bit of nuclear energy to show you. In fact, I brought along three kinds of energy and I am going to put these samples out on the table and ask you to tell me which one contains the most chemical energy. Here is a pound of dynamite. Here is a pound of coal. And here is a pound of uranium. I didn't bring a pound of butter, because I supposed I would find a pound of butter available at a food technologists' convention. We can imagine that this gavel is a pound of butter. Now, which of these four pounds of material contains the most chemical energy? Since we don't want to take the time for a majority vote, I shall be autocratic and presume to vote for you. I am going to say that you would tell me that there is probably the least energy in the butter. (I don't know whether a food-technological audience would fall for that one or not!) Next would be the coal, next the dynamite, and the greatest amount of chemical energy, I am assuming you to say, is in the uranium.

Of course, that isn't right, or I wouldn't have asked you. Lowest is the uranium, as it contains only 2200 British thermal units per pound.

Next is the dynamite, with 2300 British thermal units per pound. Then comes the pound of coal which has 14,000 B. t. u. per pound, so it is seven times as powerful as the uranium. Finally, the pound of butter has 16,000 B. t. u. per pound.

You see, it was a trick question. I know you are disappointed because you felt that the uranium ought to win. The trick was in the words "chemical energy." I was restricting the discussion to the energy you can get by re-arranging the atoms in a molecule.

What I really should do is to include the nuclear energy—the atomic energy, in which everyone is so interested nowadays. Then you would say: "Ah, now, the uranium undoubtedly has the most." But the answer still is "No," because if I include all of the energy in the atoms of each of the materials, they all have exactly the same amount. In other words, you could in theory use uranium, coal, dynamite, or butter equally well for an atomic bomb, for each has the same amount of energy. The difference, again, is one of know-how. We know how to get the energy out of the uranium, and we don't know how to get it out of any of the other atoms. According to Einstein's Relativity Theory of 1905, every particle of matter contains this energy, which, in the same units I used in talking about chemical energy, would be 29 million million units per pound.

Fortunately, we know how to get only one tenth of one per cent of this atomic energy out of uranium, but it still amounts to 29 million million British thermal units per pound.

Naturally, people worry about this a good deal. It is important not to worry too much about this sort of thing. Scientists enjoy being the center of the stage; they like to make everyone shivver about these cataclysms that they talk about. If you analyze the evidence carefully, there are different degrees of things to worry about, and we don't always worry about the right ones.

I remember seeing Halley's Comet in the sky as a small boy; we were told that we were going to pass through the tail of the comet. People were very much worried, and many predicted the end of the world. We never would have known that we were passing through the tail of the comet if the astronomers hadn't told us so.

I remember a lecture given by a scientist in 1920, who said that in his opinion, the sun was going to blow up in 50 million years. A man came running up to him after the lecture and said: "Doctor, Doctor, when did you say the sun was going to blow up?" "In 50 million years," said the speaker. "Thank God," said the man, "I thought you said 15 million years."

Here are my predictions of things to come:

I predict that atomic energy will never supplant oil, coal or even wood as a source of energy. It will supplement these, but not supplant them.

You might not realize it, but in spite of our oil wells and coal fields, there are still some 80 million people in Latin America who use wood for every purpose in the production of energy. There is now more wood cut for fuel in the world than ever before in recorded history. I predict that we are going to use all our wood, coal, and oil, and we are going to use all of the atomic energy that we can get hold of.

This is important. Nuclear energy is of a specific type and we can do things with it which we can't do with other kinds of energy. Therefore, we would be foolish to waste atomic energy on doing things which can be done as well or better with coal, oil, or wood. That is not saying that atomic energy may not be used as a by-product for doing the jobs of every-day energy. But I can tell you right now that you are never going to run your household with a plutonium pill. That is a newspaper story that is absolutely contrary to possibility. Also the atomic-powered automobile leaves me cold. Or, rather, it leaves me hot, because when people talk about the atomic-powered automobile, they completely neglect the fact that the man who drives the automobile would have to be careful to sit on an eight-foot cushion of concrete to protect himself from the damaging rays that would come out of the material being consumed, and the automobile would have to have six-foot mudguards of concrete to protect the passersby. This 100 or 150 tons of concrete takes away most of the glamor from the pea-sized nuclear engine for an automobile.

The great cataclysms that you read about in the newspapers are extremely unprobable. In the first place, they don't involve the kind of energy that we know how to release. No one knows how to tap it. There is little danger that some scientist will, quite unexpectedly, find himself releasing enough energy to blow up the world. This is the kind of energy that keeps the sun and the stars and all of us warm. It requires very careful planning even to release the one-tenth of one per cent of this energy that we know how to release now, and if it were a thing that could take place by accident, it would most probably have taken place on this earth long, long ago.

I want to conclude by emphasizing again the thing which Dr. Ball spoke about, the unity of all science. When you find cosmic rays affecting the genes of heredity, coming in and changing a cactus with prickles on it to one that hasn't any, and a tiger lily with pollen to one that hasn't any pollen—when you find such changes as these, you can see that all scientists—the physicists and the biologists and the food technologists—are really one group. I am looking forward to the day when we will be able to synthesize food as well as tear it apart. We know how to break cellulose down into starch, and we can make glucose out of sawdust. But we don't know yet how to build together carbon atoms and oxygen atoms and hydrogen atoms in space to make glucose the way Nature does it. It is true that the chemist can now make glucose out of atoms, but the trouble is that he makes sixteen kinds of sugar at the same time and fifteen of them are worthless. Glucose is really important for living. The scientist has no control of where the atoms are going to be put, and he hasn't yet learned to twist them around into the right arrangement. The enzyme can do that, but the scientist cannot.

An enzyme is a molecule, like a cookie cutter, which has the ability to impress its own imprint on atoms, and make them twist into the form desired. In nature, this goes on automatically if the conditions are right.

I am going to close with a story that happened to me a year or so ago, which emphasizes the changing role of the scientist, as a result, mostly, of the war.

This is the story of the impecunious clergyman and the sterling porter. I was riding down from Canada on a so-called Pullman car on a decrepit railroad—I won't mention its name, but it goes down through the center of Vermont. This Pullman consisted of half a car; the other half was the baggage car. The Pullman part was fitted up with six large, over-stuffed chairs, done in what I suppose was green velvet of half a century ago. The only two persons in the car were myself and the porter, who was doubling as conductor. After a while the door opened, and in came an elderly, seedy-looking clergyman, who shuffled up to the porter and said:

"Porter, I'm a poor man of God. It's hot and dusty back in the coaches there. Here are all these empty seats here. Why can't you let me sit up here, where I will be more comfortable?" "Suh," said the porter, "in the good book it says, You shall render unto Caesar the things which is Caesar's, and you shall render unto God the things which is God's." "Them chairs belongs to Caesar!"

The Moral of the story is that before the war, before the scientific revolution, the scientist was in the role of the impecunious clergyman. "Won't you give me some money to help me finance my research? If you will give $100, we may be able to make a couple of new molecules."

But you don't find that any more. Since the war, the scientist has become the sterling porter. The scientist now renders unto Caesar the things which are Caesar's, and carries on practical research. At the same time he does the fundamental research, rendering unto his old gods the things which are theirs.

Fundamental Research is the basis for all scientific and technological development in the future.

NICHOLAS APPERT MEDAL PRESENTATION

JOHN T. KNOWLES

Past Chairman, Chicago Section, Vice-President, Libby, McNeill & Libby

June 2, 1947

It has been traditional for the chairman of the Chicago Section to present the Nicholas Appert Medal as an award from that section. It is with sincere regret that I must report that an illness of several months' duration prevents the current chairman, Mr. C. C. Zeigler, from being with us tonight.

The Nicholas Appert Medal is a parmanent tribute to both the man who discovered one of the basic methods of food preservation, as well as to the distinguished recipient in whose honor we are assembled tonight.

Appert's discovery of sealing food in hermetic containers and applying heat for the preservation of food marks the origin of the modern canning industry. Pasteur's invaluable studies of the role of bacteria as food spoilage agents and the sterilizing effect of heat furnished the first scientific interpretation of Appert's methods of food preservation. The recognition of the importance of bacterial spoilage and the need of adequate thermal processing profoundly affected the later growth and development of the canning industry. Despite the phenomenal expansion of the industry in America, largely as a result of the Civil War and of World War I, the determination of the adequacy of thermal processes required for the preservation af canned foods remained largely a "Rule of Thumb" art of cook room foremen until the present century.

When the United States entered World War I, a young Kansas farm boy, then a student at Washburn College in Kansas and a member of the Kansas National Guard, went overseas as a first lieutenant in the artillery. While overseas this young lieutenant had the opportunity to formulate and test two guiding principles. These are: (1) The fastest and surest way of accomplishing a particular goal requires careful planning leading to a detailed written outline; (2) A leader gains the respect of his subordinates by his own *hard* work. The resultant recognition and admiration from his men constitutes one of the highest rewards anyone can merit. These two principles have guided our medalist ever since.

Returning to the states in 1919 as a captain, C. O. Ball enrolled in George Washington University and in 1920 received the B.S. degree. Two years later he attained the M.S. degree and in 1926 the Ph.D. degree from the same university.

While studying at George Washington University, C. O. Ball also worked at the National Canners Association Laboratories in Washington, D. C. At that time part of the work at the association laboratory concerned the relationships between thermal death times of spoilage bacteria and heat penetration rates in canned foods. The results obtained by the young physicist and his co-workers were reported in the National Canners Association Bulletin 16L, which contains the exposition of the now classical "General Method" for determining thermal processes for canned foods. Thus, a scientific approach was substituted for the "Rule of Thumb" determinations of canned food processing times and temperatures.

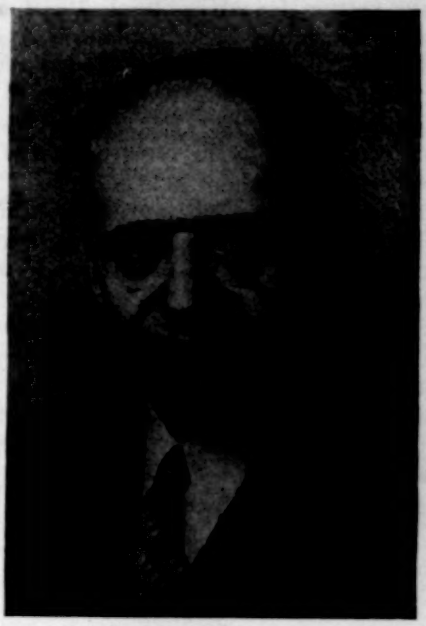
But the graphical "General Method" was too slow and laborious to satisfy the young physicist. In 1923 he published additional studies entitled "Thermal Process Time For Canned Foods" and "Mathematical Solution of Problems on Thermal Processing of Canned Food," in which he outlined the basis for rapid calculation of thermal processes from heat penetration and thermal death time data. These methods not only expedited the determinations, but also permitted calculation of equivalent processes at various retort temperatures and for various can sizes, thus

facilitating the establishment of comprehensive processing tables such as those found in the National Canners Association Bulletin 26L.

The fact that these publications were prepared while carrying on other duties at the laboratories of the National Canners Association, and later at the American Can Company, and that three academic degrees were conferred on C. O. Ball during that time, bear ample testimony of the extraordinary energy and accomplishments of the present Medalist. Confidential reports indicate that he allowed himself an average of five hours a night for sleep.

With his clear understanding of the basis of thermal processing of canned foods, Ball soon evinced a keen interest in the improvement of processing methods. A number of patents and the comprehensive publication in 1938 of "Advancement in Sterilization Methods," represent our Medalist's significant contributions to the "High-Short" principle of sterilizing canned foods. This principle has also been widely applied in the flash pasteurization or sterilization of fruit and tomato juices. Moreover, experimental work by C. O. Ball and others has amply demonstrated the advantages of applying this principle to the sterilization of low-acid canned foods. Its limited application is exemplified by certain agitating-processing procedures which take advantage of the speeding of heat penetration by agitating the containers during the processing of certain types of foods. The ultimate aim in the application of this principle involves the filling and sealing of the sterilized product in sterilized containers under completely aseptic conditions. The mechanical difficulties of such an operation have retarded commercial application, but the foresight of the Medalist undoubtedly forecasts revolutionary developments in the industry.

In the best American tradition, C. O. Ball's career exemplifies that of a self-made man whose accomplishments bespeak his character and talents. He learned to work early in life, taking care of farm chores, and, later, publishing a country newspaper. Never deterred by handicaps and always cognizant of the possibility of improving himself, he is known as a tireless worker and an example for his associates and subordinates. His friendly manner and sincere interest in the work of his associates have endeared him to all who had the privilege of coming into contact with him. These outstanding personal qualities, together with his valuable contributions to the science of food technology, make him not only a true, but also, a great scientist. It is a distinct pleasure to award this medal to Dr. Charles Olin Ball in recognition of his contributions to science and to the welfare of mankind.



CHARLES OLIN BALL
Consulting Food Technologist

RESPONSE, UPON RECEIVING THE NICHOLAS APPERT MEDAL

CHARLES OLIN BALL

MR. CHAIRMAN, FELLOW MEMBERS OF THE INSTITUTE OF FOOD TECHNOLOGISTS, GUESTS:

I would not try to make you believe that I am calm and composed. To use a term that is quite familiar to the food technologist, I am badly decomposed. I have a double reason for nervousness this evening. The first is that I am nervous by habit when anything momentous is happening to me; the second, I have a feeling of having been unfair to the Chicago Section, for which offense I wish to atone publicly.

Quite innocently, after consulting certain authorities, I used my pencil too diligently in editing, for FOOD TECHNOLOGY, the Appert Award address of 1946. I struck the "h" out of Nicholas. In calling my attention to the matter, the acting chairman of the Chicago Section, Mr. E. S. Stateler, in his usual kindly manner, complimented me on my consistency in the error but asked me to remember that in the official name of this medal the "h" is still in Nicholas. I acknowledge my error and promise that it will not be repeated. The urgency of my task of editing was responsible for my failing to refer the matter in advance to the Chicago Section, instead of simply assuming that an error had been made in setting up the article. I hope the Chicago Section will accept my apology.

Mr. Chairman, I feel immensely proud and grateful over having received this honor, but my joy is tempered by a feeling that I have a challenge extending into the future to make contributions to the advancement of food technology which will make me feel really satisfied to display this beautiful medal for all to see. In other words, I feel that the jury has been especially kind to me in granting an advance payment in honor on accomplishments which are still to be realized. I thank the Chicago Section, the Appert Award Jury, and you.

MATHEMATICS AND EXPERIMENT IN FOOD TECHNOLOGY

CHARLES OLIN BALL

Nicholas Appert Medal Award Address, Institute of Food Technologists
June 2, 1947

The use of precise mathematical methods in solving problems in science is advocated as an instrument that is potentially capable of accelerating scientific and industrial progress. The reliability of calculated results is appraised, based upon experience of the canning industry in the mathematical determination of sterilizing processes for food. The use of similar mathematical technic in other branches of food technology is suggested.

Every scientific endeavor is associated, remotely perhaps, nevertheless to a recognizable degree, with an effort to apply quantitative measurement to something.

Science has reached the stage of development which makes it apparent, not only to the scientist, but also to the layman, that all science deals with one fundamental concept—mass, or quantity. Mathematics, by means of symbols, deals fundamentally with the concept of quantity. Mathematics, therefore, is the foundation of all science.

It may be doubted by some, but it is believed by others, that all science has, as its ideal and ultimate goal, the solving of every problem mathematically, without the necessity for experiment. If the fundamental reactions of every science were well enough understood to allow their results to be rigidly interpreted, every problem could be solved mathematically with greater reliability of results than that which can be obtained through laboratory experimentation.

The only reason for following experimental procedure is to seek answers to questions which are too complex in nature to admit a mathematical solution. Most problems of science, of course, still belong in this category because their complexity puts their basic concepts beyond human comprehension.

The usual concept of science is that of knowledge obtained purely through experimentation. In the usual concept, basic research is that which produces results that have no apparent practical application; applied research is that which produces results that have an apparent practical application.

This concept is a deductive one and it stimulates a query as to what feature is inherent in impracticability which imparts basic properties to impracticable research. It seems to me that there is a more practical concept, which may perhaps be called inductive, on the basis of which scientific research may again be divided into two categories. Instead of depending for its essence upon the nature of the results obtained, this concept is tied to the nature of the procedure employed to obtain the results; in other words, to the type of problem analysis required.

While realizing that the reproducible experiment is the foundation of their present-day sciences, the chemist, the physicist, and the astronomer further realize that mathematics is fundamental in dealing with the entities that constitute the essence of their sciences. The same entities, or quanta, are basic in all sciences, but the processes of their reactions are obscure in the biological sciences because of the complex nature of the organisms with which these sciences deal. This being true, is it not reasonable to regard the extent to which mathematics can be applied within the framework of a science as a measure of the logical acuteness of that science?

Believing it to be true that mathematical processes can be made to perform the functions of experiment, I cannot agree with those who say that reproducible experiment is the only functional tool at our command for extending our knowledge of the universe.

FORCES ASSOCIATED WITH ELECTROMAGNETIC FIELDS

Whether or not precise mathematical treatment can be applied with profit in scientific work depends upon the complexity of the behavior of the simplest entity that can be involved as a unit in the phenomena that are being studied.

Complete mathematical treatment of problems within a science could occur only when the ultimate particles, electron, neutron, proton, and, possibly, meson, are involved in the phenomena that are being studied in such a way that the manifestations of the problem are traceable directly to the behavior of these particles. An analysis of the behavior of the particles thus would constitute a solution of the problem.

Foremost among the forces which account for the behavior of these particles are electrical forces. The resultant electrical force, of the forces exerted by all of the particles making up an object, produces an electromagnetic field. This force is such that it controls the behavior of the object under certain conditions. Under all conditions, this electromagnetic force has some influence upon the behavior of the object. This phase of the behavior of an entity, therefore, can be predicted mathematically when the conditions to which the entity is subjected are understood.

Biological bodies, or organisms, of varying degrees of complexity have electromagnetic fields which are explainable and predictable and to which mathematical treatment can be applied. The ultimate, precise, treatment of the behavior of complex organisms would require that their function be interpreted as the composite of the functions of the ultimate particles of which they are composed. Such resolution of functions is clearly impossible in our present state of scientific knowledge, even for the organisms of the simplest known structure.

The more complex an entity is, the more restricted, relatively speaking, is the breadth of the field in which mathematical predictions can be made with accuracy, because the greater the complexity of formation of the object, the less decisive in character is the resultant electrical force from the particles composing the object, in respect to the overall behavior of the object. This is true because the forces exerted by the many parts of the object are so nearly balanced that a comparatively small change in arrangement of these forces may produce a reversal in the sense of the resultant force.

It is to the effects of this resultant force that the initial step in mathematical treatment must be applied. For most organisms, this first step is still in the future, except for statistical treatment. For example, biophysicists have found that characteristic patterns of potential difference exist in man, but, notwithstanding the fact that electrometric technics have been applied to man's physiological problems through the electroencephalograph and the electrocardiograph, the effect of this potential difference pattern upon the behavior of man is not yet apparent. Thus, the behavior of man cannot be predicted through either a direct or an indirect application of precise mathematical formulas to electromagnetic field conditions observed in man.

Man's inability to apply precise mathematical methods to the electrical forces existing within the human and other organisms need not deprive him of the benefit to be derived from entertaining the concept that the action of these forces is mathematically precise and produces results which could be predicted if one possessed infinite scientific wisdom. This concept helps one to see the reality of a systematic and controlled relationship among all beings and among the forces that govern the existence of these beings.

In the face of our inability, because of the complexity of an organism, to apply a particulate solution which would be the ultimate precise solution of problems

involving the behavior of that organism, let us not overlook the possibility of applying to a problem involving organisms a solution similar in principle to the particulate solution, but less exact because it deals with properties of organisms instead of with properties of particles.

Measurement of electrical potential differences is a measurement of electronic forces. The field concept makes it unnecessary, however, to explain behavior by reference to particles which make up the system being studied. This concept constitutes an instrument through which the overall behavior of the system may be predicted mathematically with a considerable degree of accuracy.

As the complexity of an aggregate increases, the aggregate begins to assume a new, but simple, aspect, often resulting in new mathematics, which may be, but is not necessarily, statistical in nature. This principle may be illustrated through a concept of heat. Consider the mean kinetic energy of "n" molecules of a gas. When $n = 2$, we have the two-body problem of astronomy, which is readily solvable. For $n = 3$, it is the three-body problem, with no exact solution, but capable of approximation with some effort. For $n = 4$, an approximation is very difficult; for $n = 5$, much more so; for $n = 10$, practically impossible. When $n = 100$, we can say very little, if anything, about the aggregate, but when n is in the billions or trillions, the temperature arises. This is seemingly simple.

In the case of biological entities of less complex structure than that of animals, progress has been made toward achieving quantitative solution of problems. It is reported that, through observation of a direct relationship between measured values of electrical potential in plant seeds and the subsequent growth history of the seeds, promising leads have been provided to quantitative solution of two basic plant problems—genetic constitution and heterosis.

The mathematical calculation of sterilizing processes for food is a practical example of a quantitative solution of a biological problem which has had sufficient test to prove its value. Although its procedures are not carried into the realm of the ultimate particles, the success that has attended its use is no doubt traceable to the comparatively close connection between the behavior of those particles and that of the simplest of biological structures, the bacterial cell, to which the calculation procedures are applied. A measure of the practical value of this calculation method will be discussed later.

BASIC SCIENCE DEALS WITH BASIC FORCES

Recognizing that these matters are concerned with the fundamental essence of science, I venture to assert that scientific facts are not really fundamental until they can be generalized, or rationalized, in terms of mathematics.

For the purpose of explaining a proposed new classification of research, which is inductive in character, let us say that research that produces facts, which are fundamental under the above definition, will be designated by the non-descriptive term, "F-research"; and research which does not include mathematical rationalization, "A-research." These symbolic designations are improvised in order to avoid employing terms that are already in use in a different sense.

On this proposition, none of the biological sciences, which deal with the higher forms of organisms, has yet reached the stage at which it produces fundamental knowledge. Research in animal nutrition, for example, is carried on purely by laboratory methods. This is the type of procedure that is used in "A-research." In the biological branch, as well as in other branches of science, we find research projects in both the basic and the applied categories of the generally accepted classification, belonging in the class of "A-research"; in some of the branches, on the other hand,

there are projects in both of the usual categories, which belong in the class of "F-research."

In a broad sense, the type of problem analysis required is the same for a determination of the presence of enzymes, vitamins, or other complex organic molecules by absorption spectroscopy as for testing the physical strength of a material or for producing a method of quality control. In all of these cases, the results of experiments done previously are studied and a plan for the experimental solution of the new problem is formulated by deduction from the knowledge gained from the previous experiments.

In the proposed concept, all research which deals solely with experiments, past or present, published or unpublished, regardless of whether or not the results have an apparent practical application, would be in the category of "A-research" because it concerns only observed phenomena. An entirely different type of problem analysis is that dealing with the quanta which figure in reactions, in terms of the forces acting upon the objects involved. This is suggested as the distinguishing mark of "F-research." Although these improvised names are devoid of descriptive quality, they serve adequately, for the time being, to symbolize the distinction between two categories of science in a classification which is, as yet, only a proposal.

MATHEMATICS VERSUS EXPERIMENT

Chemists, and even physicists, sometimes are marked by their aversion to mathematics. They perform in their field solely through their memory of reactions as learned in the laboratory or from literature—with a limited amount of rationalization. Too often, scientists regard mathematics as merely a means of verifying experimental results and not as what it actually is—a potential or an actual means of obtaining answers to problems without the necessity of doing laboratory work.

Since the fundamental method of getting scientific information is through mathematical processes, one cannot correctly say that mathematics is used as a substitute for experiment. One should say that, in certain cases, experiment has not been made to substitute for mathematics.

VERIFICATION OF CONCLUSIONS

Difficulty of verification of principles and of findings is a steriotyped possession of science of the type that is usually called basic, although this characteristic does not enter into the commonly accepted definition of basic science. The findings of "F-science," on the other hand, are verified with comparative ease because of the fact that verification can be accomplished through the use of mathematics. When we recognize the close resemblance between prominent aspects of "F-science" and the concept entertained by many of the meaning of "basic," it may seem absurd to suggest that applied science may be "F-science." Applied science, however, being specialized science that deals with concrete phenomena, may or may not be "F-science," depending upon the extent to which mathematics is employed in its pursuit and its verification. This concept is in disagreement with a common notion that applied science and fundamental science are widely separated from each other.

THE FUNDAMENTAL MEASURING INSTRUMENT

I recognize the fact that, under the definition given for "F-science," there can today be no "F-research" in the biological sciences dealing with human beings or other living beings of comparable physiological complexity (animal physiology, zoology, medicine, psychology, economics, sociology), very little in sciences dealing with living beings of intermediate physiological complexity (plant physiology,

botany, horticulture, entomology), a greater but still not extensive amount in sciences dealing with living beings of the simplest physiological nature (bacteriology, biophysics), a greater amount in sciences dealing with inanimate objects of finite size (astronomy, physics) a still greater amount in sciences dealing with molecules and their component parts, with a varying degree of specificity (chemistry, electrophysics), possibly a still greater amount in sciences dealing primarily with atoms and their component parts (nuclear physics), and the greatest amount of all, in fact, total "F-research," in the branch that deals with objects of no particular class, the acts of which, in response to physical forces having an effect upon quantity or arrangement, are completely predictable (mathematics). I prefer not to call mathematics a science, but the fundamental instrument of science.

MATHEMATICS ASSISTS IN PROBLEM ANALYSIS

The study of mathematics should be regarded by the scientific student as a means of preparing himself to acquire a deeper understanding of his science and to make a greater contribution to its advancement than would otherwise be possible. Mathematical training not only enables the student to use mathematical methods in solving problems within his field of primary interest, but also enables him to think logically in attacking his problems outside of that field.

Inductive rationalization in mathematics requires the same kind of gray matter as inductive rationalization in business, sociology, bacteriology, or chemistry. The study of mathematics is the best avenue of training for rational thinking because, as stated previously, it provides its own means of accurately checking the validity of the thinking that is done. Methods of thinking that one acquires in mathematical training are applicable all the way up the line in engineering and science, wherever premises are well enough established to form a sound basis for reasoning. In fact, they are of the greatest help in deciding when premises are valid.

It is easier to acquire facts upon which to establish premises for a sound rationalization treatment than it is to acquire the ability to rationalize. In other words, it is harder to learn how to think than it is to get by observation facts to serve as a foundation for thought. This idea places less importance upon specialization in educational training than upon fundamental mental training.

SOUND PREMISES ARE NECESSARY

In time, it will become possible to establish, through mathematical processes, some of the premises upon which the mathematical solution of scientific problems is based. For the present, the premises must be established through experiment. The degree of uncertainty in premises upon which mathematical calculations are based determines the value of experiments designed to duplicate or to check results obtained mathematically. Uncertainty in premises makes experimental checks necessary. If the validity of premises is unquestionable, however, and the mathematical procedure used is sound, experimental checking means nothing because experimental results cannot be more accurate than calculated values.

PROPOSED USE OF MATHEMATICS IN FOOD TECHNOLOGY HAS BEEN TESTED

An example of the use of mathematics, to solve problems that otherwise would be solved experimentally, is found in the field of food sterilization.

To sterilize food to make it keep, heat must be applied to the food in sufficient quantity to destroy the micro-organisms of the most resistant type present in the food. Measurement of the quantity of heat employed involves two factors, intensity and time. In customary practice, intensity is variable with respect to time.

Within the food in a container, there is a location at which the intensity of heat during a process increases more slowly than at any other point. The basic problem in sterilization rests in determining when the food at this location, which we call the critical point, will have received a sufficient quantity of heat to destroy the organisms of the most resistant type that could spoil the food. Assuming that such organisms are uniformly distributed through the food, we assume that when sterilization is accomplished at the critical point, sterilization will already have been completed at all other points and that, therefore, sterilization of the entire mass of food is accomplished.

Since temperature indicates intensity of heat energy, knowledge of the rate of rise and fall of temperature at a point gives knowledge of the intensity of the heat effect at the point over a period of time. A curve showing a time-temperature relationship, usually known as a heat penetration curve, represents this effect graphically.

The quantity of heat required to destroy micro-organisms of a given type under stated conditions is also represented by a time-temperature curve, showing, for each temperature, the time necessary to accomplish destruction of the organisms. This is a thermal death time curve. By combining mathematically the results of the integration with respect to time, of heat intensities as indicated by the two curves, it is possible to find the length of time required to process a container of food.

The calculated value applies to a set of conditions which is chosen as representative of the most severe conditions that will be encountered in practice. The chosen set of conditions comes from the two sets of time-temperature curves—one based on temperature measurements in containers of food; the other, on laboratory tests on destruction of micro-organisms by heat. The choice of these conditions places symbolically at the critical point within the slowest heating container, micro-organisms of a specified level of resistance to heat.

This particular set of conditions may be difficult to obtain in experimental practice because, even with containers artificially inoculated with micro-organisms, the chances are limited that the most resistant specimen of the micro-organism will become located in the critical position in the food. Furthermore, even though containers of food apparently are identical, they do not have the same rates of temperature rise at their critical points.

HOW MUCH IS THE VOLUME OF EXPERIMENTAL WORK REDUCED?

To obtain the curve showing the rate of change of temperature at the critical point in a container of food, we consider tests on 12 apparently identical containers sufficient to give a good probability of including a container that is typical of those showing the lowest rate of heating. The curve representing the container among those tested that has the lowest rate of heating is used as the basis for calculated processes. For the purpose of explanation, we shall designate this as curve H.

For the purpose of explanation, also, we shall apply the designation, B, to the curve that shows the quantity of heat required to destroy the micro-organisms which would, if not destroyed, spoil the food. To obtain curve B, 10 samples under each of 16 different combinations of time and temperature (four times at each of four temperatures) are commonly employed in the tests. Thus, 160 samples are tested in developing a thermal death time curve.

The method of determining a process specification, which is the alternate to the calculation method, is to process, experimentally, regular containers of food inoculated with spoilage bacteria. To determine experimentally a process specification that has an accuracy equal to the accuracy obtained by a calculation based upon

curves H and B, a sufficient number of containers must be processed to carry the probability of treating, under each combination of time and temperature, a container in which the rate of temperature rise is equal to that represented by curve H, and which has, in its critical point, spoilage bacteria equal in resistance to those represented by curve B. The laws of probability establish this number of containers for each combination of time and temperature as the number of possible combinations of the samples used in establishing curve H, taken one at a time, with the samples used under each set of variables in the tests for establishing curve B, taken one at a time. The number of such combinations is 10 x 12, or 120.

Since containers in which food is packed for commercial use heat very slowly, compared to those used in establishing curve B, the range of time that must be covered in the test processes of inoculated containers is correspondingly wide and, for satisfactory accuracy, must be covered by a larger number of time variables than is required for each temperature in the tests used to establish curve B. The minimum number of process times required in a test of inoculated regular containers to determine a process at a given temperature is five. Thus, 600 samples (5 times 120) are required in an inoculated pack of regular containers to establish a process specification that has a degree of accuracy equal to that of a specification determined by calculation. For the establishment of curves N and B, upon which the calculation is based, only 172 samples are required.

To calculate a process for the same food in containers of various types, or for different processing temperatures, curve B is used for all calculations, but a new curve H must be established for each type of container at each temperature. Twelve test samples are used in determining each new heating rate, or heat penetration, curve. Thus, by running a test on 12 samples, one provides the additional data necessary to establish a process, the establishment of which, by purely experimental means, would require tests on 600 samples. Data upon which to base calculations of processes for a food in five different types of containers, processed at each of three different temperatures, therefore, would require tests on 370 samples, whereas, to find the processes with equal accuracy by experiment alone, one would have to conduct tests on 9000 containers. In applying the mathematical method to the determination of processes just to the extent indicated, therefore, one reduces the volume of required experimental work from that required by the experimental method, used alone, by approximately 96 percent.

While this mathematical method for determining sterilizing process specifications was developed without attention being given explicitly to elementary particles, the method probably should be regarded as an example of the application of precise mathematical procedure to electromagnetic forces—the forces which biophysicists describe as the determiners of design in the universe. Such forces, when associated with single-cell organisms, are of a fairly simple nature because the relationship between these forces and those of the elementary particles, electron, proton, neutron, and meson, is comparatively close. This fact, I believe, is important in accounting for the practicability of the calculation method. The method has contributed extensively to specifications of sterilizing processes in commercial practice and is a potent factor in the development of new and advanced processing technic.

PREMISES OF PROCESS CALCULATIONS NEED IMPROVING

The two curves, upon which a sterilizing process calculation is based, are now established with sufficient accuracy to make an experimental check of the calculations of questionable value. The method of establishing the curves is, nevertheless, in need of refinement. In its present state of development, the procedure for establish-

ing sterilizing processes is a border-line case in respect to the question of whether experiment should be used as a check on mathematics, or vice versa. Without describing here the lines of attack, I wish to indicate that, through a fundamental study of the manifestations of surface tension and osmosis, which originate in the electromagnetic fields, the accuracy of mathematical calculations in predicting the behavior of bacteria in food substances could be increased. Further scientific study of the factors that control the heating rates of food in sealed containers also is needed.

OTHER POSSIBLE APPLICATIONS IN FOOD TECHNOLOGY

The success that has attended the use of the mathematical method of determining processes provides evidence that a method involving the same basic procedure could be used with practical benefit in other branches of food technology. The logical approach to such use is on either the same level or a lower level of complexity than is now covered in the sphere of sterilizing processes, namely, on the level involving objects having structural complexity no greater than that of single-cell organisms. For example, complex organic molecules, such as vitamins, enzymes, hormones, and amino acids, along with bacteria, are likely objects, the behavior of which should be predictable through precise mathematical procedure.

Mathematical prediction of the growth of bacteria should be practicable, and would be as valuable in sanitation work as is the destruction of bacteria in food sterilization. Also, the prediction, by precise mathematical methods, of the chemical reactions of the complex organic molecules under prescribed conditions, as well as of the destruction of these molecules by heat or by other destructive agents, is potentially capable of vastly accelerating progress in the sciences that deal with these molecules.

New ways to advance colloid chemistry through the use of precise mathematical technic are indicated for the future. A start has already been made in the development of calculation methods to predict the effects of heat upon the quality of food.

GOAL IS FAR INTO FUTURE

In our present state of scientific advancement, it appears that the greatest benefit from the application of precise mathematics to science will come when the action is confined to objects of the class which we have been discussing—that which occupies a low position in the medium range of complexity of structure.

The elementary particles, represented by the electron, proton, neutron, and meson, are, according to present hypotheses, the bodies of simplest structure. Because these particles are extremely small, objective measurements of them are difficult to make; consequently, the evaluation of the results requires statistical treatment. Advance beyond statistical treatment will come only when it becomes possible to measure objectively the properties of single particles. Individual objective measurements are possible, on the other hand, of the properties of both complex organisms and complex inanimate objects, but, because of the extreme variability existing among individual objects in these classes, scientists here also must resort to statistics in interpreting the results. In this sphere, an advance into precise mathematical treatment will come only when it becomes possible to strictly segregate individuals according to their respective attributes.

> At this point, the suggestion is made that the reader be content with his own concept of the distinction between statistical and precise mathematical treatment. It is thought that the points advanced in this paper are valid regardless of what may be the individual reader's

interpretation of this distinction. The difficulty of presenting a close differentiation between statistics and precise mathematics is recognized, and such a presentation is purposely omitted herein.

Advancement in "F-research" technic, as defined, is bound to be slow, but sure. Every succeeding year (perhaps we should say every succeeding decade) will bring an increase in the structural complexity level of objects which will be successfully subjected to precise mathematical technic by scientific workers—with vast benefit to the rate of scientific progress.

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Current Patents and Patent Litigation

SIMPLE INVENTIONS PAY DIVIDENDS

A. J. NYDICK
225 Broadway, New York 7

In the preceding article of this series it was stated that "mere simplicity does not negative the existence of invention," and, accordingly, that a simple invention can meet the "flash of genius" test for patentability.

An illustrative instance of such an invention, and one of particular interest to food technologists is the Musher Patent, No. 2,221,404. This patent covers both the process of making an olive-flavored oil and the product itself. The patent was held valid and infringed by the Circuit Court of Appeals for the Second Circuit in *Musher Foundation, Inc.* v. *Alba Trading Co., Inc.*, 66 USPQ 183 (1945).

Musher's specification describes a process for making the product by infusing a glyceride oil—such as cottonseed, or corn, oil—with a macerated paste made from dried olives. Briefly, his process is as follows: Ripe olives are laid in layers alternating with salt. The resulting brine is allowed to remain from one to three days, is then poured off, and at the end of from fifteen to thirty-five days the olives will have lost about seventy-five per cent of their moisture, and will contain from five to ten per cent of salt. They are then removed from the brine and dried until they have lost at least eighty per cent of their original moisture; and are then ground to a fine paste. (At times it may be necessary to soak them in oil for a short time before doing this). After grinding, they are put through a rolling or colloid mill so as to achieve such a fineness that, when rubbed between the fingers, the individual particles can no longer be felt.

This paste is then thoroughly mixed with the particular glyceride oil selected in an amount of not more than twenty-five per cent of the paste—the best proportion being less than ten or even as low as one-half per cent. This infusion is carried on preferably while the oil is at a slightly elevated temperature or such as is about 160° F. to 200° F. and desirably at about 175° F. Thereafter the mixture is agitated for from one minute to several hours; and then filtered to take out undesirable solids. When possible, it is particularly desirable after the paste and oil have been mixed at the slightly elevated temperature to put the mixture through a colloid mill; and that dispenses with any period of subsequent agitation.

The two claims of the patent involved in the suit were:

> "1. The method of treating a glyceride oil to give it novel flavor and odor characteristics which comprises infusing said oil *at a slightly elevated temperature* with a small amount of a low moisture containing, dehydrated, macerated olive paste *for a short period* and then removing the olive paste solids thereefrom." [emphasis supplied].
>
> "2. A substantially stabilized glyceride oil having novel flavor and odor characteristics containing a small amount of the glyceride oil soluble constituents derived from a dehydrated, low moisture containing, macerated olive paste, the oil being substantially free of the fibers of said olive paste."

The defendant made its accused product out of a base of corn oil with a paste of black ripe olives (and some green olives for color only). Its process was described by its witness as follows:

> "The black olives are first crushed in a standard olive press and then are ground in a standard grinder commonly called a funnel grinder. This paste

> is placed in the oil and left for a certain number of days until the flavor of olives and taste of olives is discharged into the oil. This oil is filtered in bags, in filter bags, and refiltered by pressure into tanks, and when a clear greenish color is obtained it is packed in cans. . . . We press the black olives in a standard olive press. Then we crush. Then we grind in a standard funnel grinder and that paste is put into the corn oil for a length of time to discharge the flavor and taste of olives. Now when that product is finished we take some oil from the green olives crushed that we have put together that is to discharge a part of the green olive color and place into the finished product to impart a greenish color to the entire bulk of the finished product."

The Circuit Court further described the defendant's processing as follows:

> "The moisture from the black olives is extracted 'by mechanical means or dried in the sun'; salt is not used upon the black olives; and the infusion is carried on for three days. It will be noted that the olives after grinding are spoken of as forming a 'paste'; but at the trial the testimony was that they were ground only so as to pass through a sieve of a quarter inch mesh. We shall assume that this is the defendant's present practice."

The trial judge held that the defendant did not infringe claim 1 covering the process because it did not carry out the infusion at (1) an elevated temperature and (2) for a short period. He held the product claim invalid because of indefiniteness.

The Court of Appeals reversed both conclusions of the trial judge. As to the question of infringement of the process claim, Judge Learned Hand said:

> "When this process (the defendant's) is compared with that described in Claim One, two differences, and only two, appear: the process is carried on at room temperature and not for a 'short time'."

He then painstakingly discussed the specification, and the testimony, and concluded that the infusion at an elevated temperature for a short interval is the equivalent of an infusion at room temperature for a prolonged period.

Thus, as to the specification, he said:

> "The specifications speak of heating as in any case only 'preferred' during the infusion. Moreover, when dried salted olives are added directly to the oil, and put through a colloid mill, no heat is necessary; and the period of subsequent 'agitation' can be entirely dispensed with, when the paste, after being thoroughly dispersed under heat, is put through such a mill."

Then, with respect to the testimony he accepted the patentee's contention that time and temperature are correlative factors in chemical processes.

> "The undisputed testimony was that temperature and time are correlative factors in the infusion, as is generally the case in all chemical processes: i.e., the time may be shortened, if the temperature is raised, and must be lengthened, if it is not."

After making that statement, Judge Hand proceeded to apply the time-temperature correlation to the claim in order to establish the infringement thereof. Thus:

> "Claim One selects, as the combination, 'a slightly elevated' and 'a short time'; the defendant departs from this by using no heat but allowing the infusion to go on for three days at least.
>
> "When dealing with such a claim, it would certainly be wrong to divorce heat and time into two separate elements; and to hold that, because the

defendant left out heat, but greatly lengthened time, it omitted one of the constituents of the claim."

. . . . . .

"The combination of the two correlatives constitutes a single element; and, although the defendant has not adopted the combination specified in the claim, it seems to us that the combination which it substitutes is an equivalent."

. . . . . .

"Of course, the fact that verbally the infringing process is not within the claim is no objection to the doctrine of equivalents; indeed it creates the very occasion which should evoke it."

The process claim was therefore held infringed because:

"When the defendant lengthened the time and reduced the temperature, it adopted the equivalent of a 'short' time and a 'slightly elevated temperature'."

Turning next to the claim for the product, Judge Hand analyzed the defendant's accusations of indefiniteness and disposed of them in a series of statements which pithily declare fundamental principles of patent law. Thus, he said:

"The attack upon Claim Two is based solely upon its indefiniteness; the defendant challenges it because it does not sufficiently describe the product . . ."

. . . . . .

"The first objection is that the introductory clause tells nothing: 'A substantially stabilized glyceride oil having novel flavor and odor characteristics.'"

Then followed the basic relationship of a claim to the specification:

"As in the case of any other claim, a product claim may, and indeed must, be read upon the specifications: its terms are no more than a shorthand from the fuller explanation which the specification should contain.

"Whatever may have been the recent tendency of the Supreme Court to bear more heavily than in the past upon indefiniteness of diction in the claims, there can be no doubt, at least in the case at bar, that all the terms used in Claim Two are anchored in the specifications, and do not speak in terms of function."

. . . . . .

"To proceed to the details: the specifications define 'substantially stabilized' in the following passage: 'Materially improved in keeping quality, and it is frequently possible to extend the life of a glyceride oil by three or four times' (p. 2, col. 2, lines 12-14)."

Judge Hand then added his own parenthetical observation that the word substantial had not only received the approval of the Supreme Court, but that it must always be implied

"('substantially' is not of itself fatal to a claim; Eibel Process Co. v. Minnesota & Ontario Paper Company, 261 U. S. 45, 65: indeed, it must always be implied in every claim, even when not introduced, and adds nothing when it is. Were this not true, few patents could give any protection, for some departures, from the precise disclosure are nearly always possible without losing the benefit of the invention.)"

He proceeded then to show that the words charged with being indefinite were indeed anchored in the description of the invention.

> "The specifications several times describe the words 'novel flavor and odor' (p. 1, col. 1, lines 3 and 4; lines 26-34; p. 2, col. 2, lines 8-10; lines 26-28, lines 32, 33); indeed, they scarcely need any description, being themselves self-explanatory."
>
> . . . . . .
>
> "Again, the specifications define the word 'small' by limits in defined percentage (p. 2, col. 1, lines 49-52; col. 2, lines 3, 4)."
>
> . . . . . .
>
> "Finally, 'substantially free of the fibres', means 'filtered' or 'centrifuged' (p. 2, col. 1, lines 60, 61; lines 74, 75)."

Then, in a concluding shaft at the defendant which discloses that the Courts still accord meritorious inventions the protection to which they are entitled, Judge Hand said:

> "It is impossible to suppose that anyone who really wished to respect the patent would have any difficulty in identifying what the claim covered."

The opinion is also of noteworthy interest in that it decided that the product claim was a claim for the product of the process and not a claim for an imitation olive oil. Thus:

> "We agree with the [trial] judge that 'manufacturing an imitation olive oil by infusing a macerated oil paste from dried olives, into glyceride oil, is not what was patented'; but we do not agree that the ingredients of the product and their proportions are not incorporated by reference. The claim describes a glyceride oil into which there has been infused those constituents, which will dissolve out of a specified proportion of a dry, macerated olive paste, all of which is to be found in the specifications."

Apparently the defendant had contended that a claim for a product had to define the product in terms of specifically identified ingredients, and had urged that a claim which merely defined a product that results from the manipulations of the starting materials was invalid. The Court disposed of that contention as follows:

> "There is no ground whatever for supposing that General Electric Company v. Wabash Appliance Corporation, supra, 304 U. S. 364 (37 U. S. P. Q. 466), meant to hold that the claim for a product may not be the claim for the product of the process described in the specifications.
> "Indeed, were this not true, it would always be possible to escape any process patent by making the product outside the United States, and importing it; the principal, perhaps the only, office of a product patent is just that."

Judge Hand then pointed out that, when a patentee holds a patent for a product resulting from a particular process it is questionable whether a similar product, made in a manner entirely different from the described process, infringes the product claim.

> "Rather the doubtful question is, when a patent describes a process, whether it can cover any other product than that made by the process. The patentee by hypothesis had contributed only the process; and it is not often that the product merely as such: that is, merely as a new conception—will satisfy the test of invention."

The court's interpretation of the product claim as a claim for the product made by the process described, is an illustration of the protection a court will give to a

patentee when it is persuaded that the inventor really has made an invention. An imitation olive oil—that is, a glyceride oil containing olive oil was old. What Musher did was to utilize the glyceride oil to extract from the macerated olives those principles which were extractable at an elevated temperature during a short period of time; or correlatively—at room temperature for a long period. Clearly the ultimate product was a new composition of matter, and it was defined by the claim—not in terms of a combination of specific ingredients—but as the product resulting from the described process.

The question naturally arises, in view of the court's interpretation of the claim as one for a product-by-process, whether a product having the same composition (that is, one falling within the ambit of the claim) but made in a different way would infringe the patent. For example, if it were possible to extract, by means of a chlorinated hydrocarbon, the same principles from the olives as is accomplished by the described process, and this extract were treated (say by distillation) so as to obtain a residue that could be added directly to a glyceride oil, would the resultant product infringe? The answer appears to be, No.

This clearly points out the importance, if one desires the broadest protection for a product, to claim it directly as a combination of specifically identifiable ingredients, and not as the article obtained by subjecting materials to a series of treatments.

The decision also points out the need for a full and complete description of an invention, and particularly the absolute necessity of carefully defining what is meant by terms such as "short," "long," "elevated temperature" and the like.

Finally, it is to be noted that the preparation of a patent infringement trial requires the parties carefully to assemble and clearly to present scientific and technological facts so that the court will be able readily to comprehend and accept the data or conclusions on which they rely.

Industrial and Legal Viewpoints

ORGANIZATION AND MANAGEMENT OF RESEARCH AND DEVELOPMENT [a]

L. E. McCAULEY
Armour and Company, Chicago, Ill.

Nearly all food industries need research and development. However, tangible results of research cannot be expected in a short time. Systematic but flexible organization is required to cope with the great diversity of problems in food research.

Research management should be independent of Sales or Production Departments but must be largely guided by economic consideration in the choice of research problems. Research direction without destruction of individual initiative is essential. The costs of maintaining a skilled research worker are high. Provision of the best facilities, auxiliary and related services economize his time. Close coordination between research, development and production departments is necessary through the entire course of creation of new products.

I have been asked to talk to you today on the "Organization and Management of Research and Development." It is with a feeling of humility that I, a layman, come before you, a group of technologists, to talk to you about your business, however, my pride in our organization has helped to overcome my humility, and here I am. While this talk, of course, will be upon research and development in general, it is patterned largely upon our own unit with which I am most familiar.

Organization

In the first place, we have what we consider almost an ideal set-up, that is, a combination of scientists and business management, as all too frequently the scientists are too scientific and the business managers too little scientific, so that where there is a combination of these two it is more apt to steer a course to the best interest of the company they serve.

The supervision is by an executive officer entirely distinct from sales and operating departments.

Nowadays practically all companies, large or small, need research and development. The food industry has found that the organization and operation of a research and development department is a necessary part of its business. This is true for a number of reasons. Among the most important are: to produce better products in an attractive form at a minimum cost to the consumer, and to take advantage of the best knowledge in nutrition for the processing and packaging, warehousing and distributing operations.

The size and importance of the company may indicate whether it should set up its own laboratory or arrange for this work to be done outside—in a university, a cooperating laboratory, a foundation or a commercial laboratory of which there are quite a number. Sometimes, as in our own case, it is desirable to work through all of these channels. For instance, we have our own laboratories for both pure and applied research. We are, also, members of organizations that have laboratories for the industry. We have fellowships in various universities, and from time to time we assign a special project to a commercial laboratory or research foundation.

The food industry as a whole is credited with spending only one-half of one per cent of its gross income on research and development. While percentagewise

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this seems small, in terms of dollars the amount is quite large due to the fact that the gross business of the food industry runs into billions of dollars. Since the food industry is one of the oldest businesses, and food habits have not changed too greatly over the years, food producing companies have not had to develop long lines of new products to satisfy their customers and stay in business, but they do have to develop new technique in order to keep their place in a competitive way.

In setting up a research organization, the first important step is securing a director of research, with sufficient experience and knowledge of your own particular business so that a general plan can be evolved covering the field that you expect to have explored over a period of several years, and, of course, establishing a budget about which more will be said later. The director of research is then given pretty much of a free hand in the selection of his personnel.

At first glance, the organization of a research and development department in the food industry might seem to be a simple matter, only requiring the hiring of a suitable number of technically trained people, and providing them with facilities with which to work. Actually, the organization of a research and development department requires a great deal of planning and foresight so that the organization functions as a team as well as a group of experts in their respective fields. The training required for the personnel in a food research laboratory is quite varied. In smaller organizations the training needs to be broad and can well be described by the term "food technologist." Many colleges are giving courses in this type of training and their graduates are expected to know a little bit about all aspects of food research.

For the larger food research laboratory more specialization in the training of the personnel is required. In this larger organization men with special training in inorganic and physical chemistry, organic chemistry, biochemistry, bacteriology, process engineering, and other specialties can be drawn together as a team which has a high degree of probability of success in some of the more difficult problems that may be presented.

If the laboratory is of considerable size the staff, of course, must be divided into groups; each group in charge of a leader and given a separate section of the work to be done. Sometimes work on a large project will spread over several sections, in which case, from time to time, these group leaders of the sections involved will have discussions of the problem, each one relating his progress or his difficulties for the benefit of the others, which enables them all to keep on the course toward their definite goal.

When something new has been discovered, either as an entirely new item or an improvement over something that is currently in production, it is passed from the research laboratory to a pilot plant in the development section where it is further streamlined on a semi-production basis. Sometimes snags are found at this stage, which necessitate sending the problem back to the research laboratory and, of course, the work is then coordinated between the research laboratory and the development laboratory or pilot plant until practical ways are found to produce this item satisfactorily on a factory scale. It is then turned over to the production department and, of course, followed into production by the development group until such time as it is working smoothly and is entirely understood by the people into whose charge it is eventually given for permanent production. There is rather a close working arrangement at all times between the development department and the production department because from time to time defects in production arise which the development staff is called upon to correct.

In the food business, as you all know, the raw material with which most of us work is a product of nature and, therefore, not exactly uniform at all times, such as are the parts of a machine or anything else turned out mechanically by a factory.

This lack of uniformity of starting material in foods is a very good reason for scientific organization and control in order to have a product that is uniform.

It is quite the popular thing to print an organizational chart, showing various departments and sections as they are supposed to be set up and to function. This organization chart should not mislead the uninitiated into believing that once the chart is symmetrical and looks nice on paper, that the problem of organization is complete. Since the objective of the research department is to obtain best results with the material at hand, many times it is expedient and useful to cut across the organization chart lines and obtain results which could not have been obtained had the chart been strictly followed. Neither does a good organization chart or set-up insure that good work will be forthcoming through the operation of that organization. The prime requisite is to have the proper skills, the proper abilities, the proper personalities, and the proper enthusiasm tacked on to the names which fill the squares in the chart. Without this, beautiful laboratories, equipment, money, and all else are very largely wasted. Thus it becomes essential to understand that organization and management cannot be considered separately, but must be considered with respect to its relation to each activity. Good organization cannot be built without good management, nor can a good organization produce its best results without good management.

It is quite apparent that within industry and, in fact within scientific organizations themselves, there is some misconception and lack of thorough understanding of the meaning of the words *research* and *development*. By some definitions, organizations that are one hundred per cent devoted to development work and trouble-shooting in plants are called research. On the other hand, some organizations permit a great deal of research to be done by groups that are well qualified in development but, perhaps, not so well qualified for good research work. One of the needs of management is to understand this difference and to utilize their scientific staffs to their highest abilities and avoid trying to do research with non-research people, or trying to do development with strictly research people.

The research laboratory should not be concerned with the day to day problems met in operation and sales, but should be devoted to basic problems. Development work, on the other hand, should be, and needs to be, in or very near to the factory, as it can and should be helpful with operational problems. Being close to the source of production it has available quantities of material for the pilot plant and other development work. This does not mean that the research and development organizations should operate as separate entities, but the research group should be called upon only when the trouble goes beyond the field of the development group. It is the duty of and the necessity faced by management to coordinate and integrate the work of both groups, seeing that both are fully advised as to problems, objectives, and needs of the other.

Good management of research and development necessitates the handling of many routine operations that will come to any business enterprise. The planning of the work must be done so that each job receives its proper share of attention and effort.

New ideas for research and development work and new products come from throughout the organization. Production departments have their needs that demand attention for better methods and processes. The sales organization wants new and better products, better packaging, and better values.

All of these wants and needs that seem possible to satisfy through research and development are channeled to that department. If the cost of the work is commensurate with the prospective returns, then the work is given its proper priority.

Ideas from the research and development department come in a steady stream. So many suggestions and ideas are accumulated that the management has many hard decisions to make in selecting those things to be put aside, either temporarily

or permanently. A live and aggressive organization always has several times more problems to work upon than can possibly be handled. A group lacking this characteristic is not worth its cost.

Over-organization must be avoided in managing the laboratory. Anything reasonable to keep the researcher in a normal frame of mind while at work should be done. It is a grave mistake to allow someone, either a supervisor or someone in the business management, to attempt continually to standardize and regulate those things which cannot be standardized. You cannot standardize thinking, and the beginning and source of all research is thinking.

FACILITIES

It is a waste of space and money to house the research laboratory in some abandoned space or building. The building to be used for research should be specially designed for it. The cost of maintaining a research man is so high that the best facilities should be made available to him. In a modern progressive firm, the size of the laboratory will double in five years, and in some organizations started in recent years the rate of growth will be much faster. So the design of the building must allow for expansion.

Many auxiliary and related services and facilities are a necessary part of the research organization. Besides laboratories and pilot plants, provision needs to be made for office space and staff, records and reports—including a quiet place for report writing—and meeting and seminar rooms with necessary equipment. A machine shop for making some of the special apparatus, and often for emergency repair and maintenance of apparatus, is very desirable.

A good storeroom is necessary in which the chemical research people can quickly obtain what they need for carrying on their work. A physical or engineering laboratory will have need of pattern shops, foundries, and other special services.

A library, and any size laboratory warrants it, can save a lot of needless expense and work by providing technical information on what has been done before, and will often indicate trends of thought in scientific fields. The larger the research group the larger the library staff needs to be. In any case, the technical people should be allowed to utilize any library facilities that are available in the community.

Another department that is indicated, if the research laboratory is large enough, is a patent section. If the research group is too small, it would be advisable to have one of the technical staff, or even the director himself, act as a contact between the company and its retained patent attorney.

It is not economical of a research man's time to expect him to do the routine analytical work connected with his research. It is faster and better to provide an analytical laboratory where even more than standard analyses can be made. Some special analytical procedures need to be done by the research worker, but as soon as possible these special techniques should be placed on a routine basis.

MANAGEMENT

The money invested by industry in both basic and applied science, through a well organized research and development department, is capable of producing the desired results with far less risk than some of the other company operations. The potential profits from such financial venture is greater than most other company expenditures. In research, when a new method or product has been developed, the company reaps return from that particular effort indefinitely.

Management should guard against the unwise expenditure of time and money on unworkable ideas that are sent in by enthusiasts in and out of the company, as well as to bring to a successful conclusion those ideas which are good. Incidentally,

it would save a lot of time and money if unsuccessful work were reported and recorded, either to avoid repeating a failure or, perhaps, in the light of a newer knowledge, to devise a new line of approach to this problem.

From recent surveys we find that it costs somewhat over $10,000 a year to maintain a research chemist. This, also, includes the salaries of a non-technical assistant, stenographic and janitor services, and overhead which includes rent, and the maintenance of the physical plant. This figure will vary from company to company depending on the type and amount of research done.

For good management of research and development, budgeting and accounting are necessary procedures. It is desirable to know how much money is expected to be spent on research and development as a whole, and to some extent, how much will be allocated for some projects. This permits the consideration as to whether very expensive projects are worthwhile based on the prospective returns. Most managements, nowadays, are aware of the fact that research results cannot be expected in a short time and are thus prepared to spend money on research for some years without expecting immediate tangible results. This is sometimes called patient money. Research budget should not be subject to fluctuations with earnings. Research workers cannot be released and hired as can production workers. Release of research workers causes the company to lose its investment in the training and experience in these workers. Too complicated an accounting procedure is to be avoided. The results of the research and development work need to be accounted for in detail merely to indicate whether the department is paying its way. In accounting for projects completed, on which the company is receiving financial return, it is quite important that the research department should claim credit only for those things, or its share of those things which rightfully belong to it. The research department can afford to be generous in giving credit to production or any other department for its share.

PERSONNEL

Management's first responsibility is the choice of the research and development personnel it expects to weld into a successful department. The kind of training and experience needed in the staff is not difficult to appraise. Evaluating other characteristics of the individuals needed for good teamwork is not too easy. The members of the group need to be able to work in harmony with their fellows, and to contribute their share to the general level of morale of the group.

An average group with a good esprit de corps can accomplish more than a group of more highly trained but non-cooperative persons.

A scientist takes pride in his work and reputation. He is encouraged to prepare scientific reports for publication. He is allowed to attend those scientific societies in which he is a member, possibly not each meeting, because of the numbers involved, but in his turn.

Seminars in the department give him an opportunity to explain his work to his associates. In addition to group meetings an occasional get-together of the whole department is a useful procedure.

All such actions sponsored by the management aid in the collaborative and cooperative attitude that means much in good team work and adds to the enjoyment of the job. Hard jobs seem easier if the workman enjoys his work.

In summary, the requisites of a good research and development department are:

1. A good director of research
2. A well chosen staff
3. Adequate compensation for work
4. Adequate facilities
5. The allowance of a free hand in conducting its own activities

6. The allocation of budgets for general expenditure
7. Should be controlled by its own executive officer, and not by sales or operating executives
8. Allow opportunities for contacts and participation in professional society activities. Should encourage the publication of scientific papers, after due allowance for timing to protect the company's interest
9. The delivery of a profit and good results is obligatory eventually. Investing in research is the same as investing in a security. A return is expected from each.
10. The keeping of the company's business and potentialities in the foreground at all times.

If the problem of management of research and development is approached with a combination of science and business considerations, good results are assured. A poorly organized and managed department is an expensive luxury. A well managed research department is well worth its cost.

A good research organization is an asset to a company as an adjunct to advertising; as a consideration in bankers determining a credit standing, and as an assurance to customers on quality of products.

If the research department is successful in encouraging new lines of thought, and new endeavors by the rest of the company, its operation has been worthwhile.

RELATION OF TECHNOLOGY TO COMPANY MANAGEMENT*

PHILIP W. PILLSBURY
Pillsbury Mills, Inc., Minneapolis 2, Minn.

Research appropriations are investments in the future which should be established under a broad policy that is independent of fluctuations in sales. The author believes that control laboratory work can be done satisfactorily by an operating group, but that research should be confined to the Research Department, the Director of which participates in central management. Such an organization should provide the means of selling a worthy research program to management, the Board of Directors, and stockholders.

Mr. President, Dean Prescott, Ladies and Gentlemen: After that introduction I would be wrong in saying I was a little nervous in coming up here to speak on the relations of technology to management—with my passing grade of professional English at Yale University and my 2,000 word vocabulary—but I do feel that I can put over my simple message and that I know a little about the subject that I am so enthusiastic about.

It is rather difficult to comment on a subject that has been so well covered by great men like Dr. Bush, institutions like the I. R. I., or, more recently in the message you have probably read in the papers this morning, from Dr. Compton, on the need of national defense, with his emphasis on the committees on research as an example of team-work in the management of our great country.

Now, generally speaking, I feel that the trouble with this whole problem of research relation to management is this: All corporations and companies are owned by stockholders, and they elect their Board of Directors, expecting the Board to be on the gun to see that there is a dividend quarterly or annually. The President of that company is also chosen under the gun, and much too often he is influenced by the day to day profits that he feels are necessary in order that he may continue his job and to continue the job that the company has been organized by the stockholders to carry on.

Probably some of you remember that several years ago—and I don't blame anyone—when I was asked to be President of the Pillsbury Flour Mills Company, there was a great deal of criticism from Wall Street, and other financial sections, as to "Why are they picking a stockholder, a member of the family, to run this sleeping giant? Why haven't they got somebody in the corporation who can really buckle down and turn out bigger profits?"

Well, I hope that during the past seven years I have answered my critics, but if I haven't I will continue in the firm determination that I am in an enviable position, because I didn't go into this job to make money for myself or to gain power. I went in because I am proud of the name of Pillsbury (there are only a few companies bearing our name in the United States). It gave me an opportunity to satisfy the stockholders and the Board of Directors, to prepare plans and go ahead, and look into the future. We do not care so much if they do not approve all our plans—we can step aside and let somebody else take hold—but I don't have any trouble in selling my Board of Directors a long range program. We have many five year programs paid for at the present time.

We have no trouble, as so many companies have, of starting and stopping research—one year they have a big appropriation and then, as earnings fail or are

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low, it is necessary to curtail research. I don't have the problem of comparing the expenditure for research to percentage of sales.

Anybody in the milling business—or in the food business—if he ties the expenditure of research to the sales problem is 100 percent wrong. Wheat at $3. a bushel, as compared to several years ago at 66c a bushel, or flax at $7. a bushel against $1.25, is going to make a whale of a difference as to the dollar sales value to you, and that has no relation to the necessary spending for research.

I don't have the problem of worrying as to whether I will have 40% long term research expenditures, 40% short term and 20% control; I don't have to worry too much as to whether the supposedly perfect 30% expenditure with institutions and universities is the figure on which we operate or whether we are spending more on the outside or on the inside. I believe in investing in the future, and therefore I support a long range research program.

In order to give a little more of the background concerning this first point, I would like to explain our company's set-up. We are set-up like a holding corporation, of which I am President, and I have four officers as a Management Committee—a Comptroller, a Treasurer and two Vice-Presidents—one who has had training in manufacturing and research and the other who has had training in sales. We are the "Old Guard." We live in a "castle." We meet every day. We do not operate any of the operating divisions. We have six or seven divisions of the company with their division presidents and officers. They are the boys who are under the gun. If they don't produce profits, we are compelled to make changes and we do that hurriedly, but we don't have research reporting to the division presidents. Research reports to me and I feel right here that the Vice-President of Research should be a man who has balance and who knows something about business and also who has a background of research. He should report to one of the top management officers, either the President or the corporation Vice-President. If I am out of town my Vice-President reports to the committee that meets daily, and there is no waiting around for policies that have to be decided. In this way the Vice-President of Research reports to one boss. We have a two-way flow of information and understanding. In that way I look upon research as the heart of the organization, the beating and throbbing, as it pushes new ideas backward and forward, like pilot plants, right at headquarters. Many times in the past we have had experiences in attempting to build pilot plants and maintain them outside of Minneapolis but we have always returned to our plan of having everything right under the top management's nose.

In this way I differ a little bit with Dr. Kettering and others, who feel, of course, that most research should be headed up by the top management in the holding company but that some research can be done by an operating group. Maybe I misunderstand what research means. If Dr. Kettering and others mean control work and development work, why, of course, the operating companies should have their organizations. We in our feed organization headquarters in Iowa conduct day to day research with batches of chickens, cattle, etc., but we don't include that in our research appropriation as such. That is control laboratory work and falls in a different classification.

So, my first point, of the three points I want to make concerning the relationship between research and management, is that management must be sold 100 percent on going forward and supporting research adequately.

To carry on now to point No. 2—this is selling the Board of Directors, and selling the stockholders, the idea that research is an assurance for the future. If a statement just recently made is true, however, that only 15 percent of the companies earning $100,000 or more gross, a year, have research divisions, we have a long

way to go to sell owners of companies and stockholders this idea. In connection with the second point, it is up to management to keep research "on the beam" so that it appeals to men in production or serves as a selling point to the stockholders. It must justify an expenditure of money for research in long term projects, upon the results of which you cannot immediately put your finger or demonstrate the financial return.

Now in the meantime, you Ph.D's and you Masters have a pretty easy time. There is a shortage of you gentlemen, and, as I understand it, there will be a shortage for many years to come, so that maybe some of you haven't a feeling that you have to kow-tow to the owners of the company that you are working for, or, if you are in universities, to that portion of the work which comes from business and outside sources. Everyone in this room knows, however, that the M.A. and B.S. degree boys who are coming out of the universities—the poorer ones—are not getting jobs. We are getting, as far as the Mid-West is concerned, a large number of applications and in time the personnel will catch up to research requirements as a whole. I do say, on the other side of the fence, that anybody who has taken the time required and has struggled to get a Master's degree and a Ph.D. degree—which I regret to say I do not have—must have in him that something that it takes to direct successfully the work in a research laboratory. On the basis of satisfactory work in the Laboratory, management and the President of the company have something with which to go to the Board of Directors and the stockholders, when the budget comes up, and say to them, "Yes, we are going to go ahead with research next year and we are going to spend more money on research than we ever have before." You scientific men supply the material for selling the stockholders, and then in team-work with management, you can go ahead and continue to support increases in your budgets.

All we have to do in the food game is to show our stockholders that research in the hands of our competitors is a threat but research in our hands is an assurance that their money and their dividends are protected now and in the future. So point No. 2 is selling this research and team-work with management to the stockholders.

And finally we have to win the race; we have to win the game. Perhaps, because just twenty-four hours ago I was straining my back and arms in a heavy blow trying to win a sailing boat race, I would now like to compare this team-work to sailing, sailing on the beam.

We go to our Research Department and we try to sell them our program. So let's take the sail boat race, with myself as skipper and a crew of five—the man on the main sheet as sales executive, the man on the jib as the Purchasing and Steering Department and the man in the light sails as the Sales Department, etc.

First, we tell our Research Department that we are not interested in just any kind of research—we are not interested in steam boats and other fishing vessels, etc.—we are interested only in sail boats. So we narrow them down to the food game, and then we tell them what class we are going to sail in, whether in a small boat or a large boat—a small company or a large company. In that way, we limit their activities and get research on the beam even more.

Then when they know that we want to come out in first place, as with equipment, why, they start producing—and that is what you might call controlling development—the hull of the ship and the sails. And then we have our tune-up race, and maybe we come in fourth, or, perhaps, we find our place in the tune-up race and then suddenly see that something has gone wrong—the package has not been developed properly or the taste is wrong, the flavor is wrong, and so on. In other words, the sail doesn't set right on the ship and we have an opportunity to go back and develop that point. Finally, when a race covering a certain product comes up, perhaps we come out first or second—simply because research during the last two or three years